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EXPERIMENT PLAN FOR THE RVACS/RACS AIR-SIDE FULL-SCALE SEGMENT TESTS IN THE ANL NATURAL CONVECTION SHUTDOWN HEAT REMOVAL TEST FACILITY

by

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ABSTRACT

The use of natural air circulation as a means of shutdown heat removal from a reactor vessel is an important feature of current LMR design concepts because it will effectively improve safety, lower plant costs, simplify plant operation, reduce construction time, and enhance plant licensability. The method of shutdown heat removal proposed in IFR/LMR designs utilizes a passive cooling system referred to as the Radiant Vessel Auxiliary Cooling System (RVACS or RACS), which rejects heat from the reactor by radiation and natural convection to air.[1,2,3] The actual system consists of several concentric segments - the reactor vessel, the guard vessel, and the shell or duct wall. The Argonne National Laboratory (ANL) Shutdown Heat Removal Test Assembly simulates an air-side full-scale segment of the corresponding RVACS/RACS systems.[5]

The guard vessel and duct wall are simulated in the ANL Shutdown Heat Removal Test Assembly by two parallel plates, which are quite prototypic of the corresponding system because in the actual RVACS system $R >> h$, where R represents the radius of the guard vessel, and h represents the air gap between the guard vessel and the duct wall. Consequently, there exists geometric and kinematic similitude between the RVACS/RACS models and the ANL prototype, which means that the velocity profiles of the corresponding system are proportional in magnitude and identical in orientation. Hence, heat flux patterns are expected to be representative of the corresponding system.

The test assembly consists basically of a 5-ft. by 1-ft. rectangular duct system about 86-ft. in overall length, which has an entrance region ~ 5-ft. in length, a heated section ~ 22-ft. in length, and an outlet duct system and exit stack ~ 59-ft. in length. It is sufficiently instrumented to measure and record local wall and air temperatures, velocity profiles, surface emissivities, and conduction, radiation, and convective heat fluxes at various elevations. Heating of the simulated guard vessel wall is achieved with an array of 200 ceramic plate electric heaters. The computer controlled heating system is designed to operate in two modes - constant temperature control mode, which is capable of independently controlling the ten 2-ft.

high by 5-ft. wide zones of the guard vessel at any constant temperature up to 1000°F, and constant heat flux control mode, which is capable of independent constant heat flux control of the ten zones for heat fluxes up to 2.0 kw/ft^2.[5]

An experiment plan for the RVACS air-side full-scale segment tests in the ANL Shutdown Heat Removal Test Assembly has been developed and is presented herein. It should be noted that, although this initial plan is oriented toward the characterization of the RVACS (GE-PRISM) performance, the major facility components and procedures have been designed to accommodate variations in guard vessel/collector wall configurations to simulate other passive heat removal designs. For example, near-term planning is in progress to install fins on the collector wall to simulate the RACS (RI-SAFR) concept following the completion of the RVACS experiments. The intention of this document is to supply basic information about the test plan, and to that extent it will:

1. briefly review the nature and purpose of the ANL RVACS/RACS test program,

2. define the test objectives, conditions, and requirements, and

3. describe the experimental hardware, computer control and DAS, planned test performance operations, quality assurance, safety considerations, documentation, and project organization.

The results of the test data analyses will be promptly assessed and reported in accord with program requirements.

1.0 TEST OBJECTIVES

The fundamental test objective is to experimentally measure the thermal and hydraulic air-side performance of a prototypic passive heat removal system. Consistent with that fundamental objective, the initial Phase I testing objectives shall be as follows:[6,7,8]

1. Initial checkout and isothermal/hydraulic characterization of the system consisting of heater control and bake-out tests, and complete instrumentation and data acquisition checkout.

2. Obtain system performance data for the range of Reynolds Nos. (Re) = $0.25 - 1.5 \times 10^5$ for constant temperature controlled test operations at 250°F, 600°F, and 900°F, by varying the total loss coefficient (K), from the system minimum of ~ 1.5 to its maximum of ~ 20 for each temperature setting.

3. Obtain system performance data from simulations of several possible vertical temperature profiles of the guard vessel, which may be subjected to a maximum temperature of 1000°F.

4. Obtain system performance data based on constant heat flux control mode of operation for target heat fluxes of 0.5, 1.0, and 1.5 kw/ft^2.

2.0 TEST REQUIREMENTS AND CONDITIONS

Consistent with the fundamental test objective, and pretest analyses, the basic requirements and conditions for the ANL Shutdown Heat Removal Test Assembly have been characterized as follows:[5,9-17]

1. It will geometrically simulate an air-side full-scale segment of an RVACS/RACS systems.

2. It will be capable of two modes of operation that can produce constant or variably controlled guard vessel wall temperatures up to

1000°F, and either constant or variably controlled heat fluxes up to 2.0 kw/ft^2.

3. It will be capable of simulating system total velocity-head losses from a minimum coefficient (K) of ~ 1.5 to a maximum of ~ 20.

4. It will be capable of simulating Reynolds Nos. in the range of Re = 0.25 - 1.50x10^5.

5. It will be capable of simulating variable gap widths up to 18-in. between the guard vessel and duct wall.

Additional comments regarding the general operating conditions and requirements for the planned tests are as follows:

1. A straight entrance will be used for the Phase I tests, which will be instrumented for the measurement of entrance air temperature.

2. Incremental variation of total velocity-head loss coefficients K from ~ 1.5 to ~ 20 will be achieved by changing the cross-sectional area of flow with fixed area dampers, which cause local flow restrictions that change the K factor.[18,19]

3. System characteristics such as velocity, Reynolds Nos., and loss coefficient K will be referenced to the inlet of the heated test section.

4. Forced flow testing conditions require that the slide damper be completely closed, and the fan be operated at an optimally adjusted speed while the butterfly damper valve is open.

5. Natural convection test conditions require that the fan be off, the butterfly damper valve be completely closed, and the fixed area dampers be inserted to produce the desired flow conditions.

6. Weather condition considerations for testing are as follows:

- Test operations will remain flexible, sensitive to weather conditions encountered during the scheduled testing period, i.e., to the extent possible, sets of target parameters will be repeated for widely varying meteorological conditions.

- Procedures will be devised to determine and account for data anomalies related to changing meteorological conditions.

- The outdoor wind velocity, direction and temperature at the stack exit will be monitored for verification of any effect on the test measurement data.

7. The roll-up door entrance to the test assembly area will remain open for the majority of test operations.

8. The building exhaust fan will not be operated during the system performance testing operations.

3.0 TEST ASSEMBLY DESCRIPTION

The ANL Shutdown Heat Removal Test Assembly, referred hereafter as the Test Assembly, is designed to simulate experimentally passive heat removal systems (initially the GE-RVACS system), which remove decay heat from a reactor vessel primarily through radiation and natural convection to air. The initial Test Assembly configuration supports the requirements of the reference GE RVACS design as well as future modifications. The experiment design refers to the structural design configuration that is based on a modeling analysis and system performance evaluation that predicts that a smooth air-flow channel with no fins provides adequate performance. Possible design improvements would incorporate modifications to the current design such as changing the entrance and/or exit weather cap, the channel air-gap spacing, and/or adding fins, ribs, or variable roughness.

The Test Assembly is basically comprised of a structural model, electric heaters, insulation, instrumentation, and a computerized control and data acquisition system. Experiment operations will simulate prototypic guard vessel temperatures, air flow patterns, and heat removal conditions that would exist for an RVACS system during normal operation and/or a shutdown situation. The system will be operated in either of two thermal modes: (1) constant temperature or (2) constant heat flux. In constant temperature mode the capability exists to control the guard vessel wall at any temperature up to 1000°F in any of the ten 2-ft. vertical zones of the heated section. In constant heat flux mode the capability exists to control the heat flux through the guard vessel wall at any value up to 2.0 kw/ft^2 in any of the ten 2-ft. vertical zones.

The individual systems of which the Test Assembly is comprised, namely, the mechanical, electrical, instrumentation, computer control and DAS systems, will be discussed in more detail below in Sections 3.1 through 3.4.

3.1 Mechanical Systems

The mechanical systems refer to the entire mechanical and structural apparatus of the Test Assembly, and related physical and functional details. Figure 3-1 shows the basic configuration of the apparatus in relation to its surroundings at the testing site in the "pool area" of building 310 at ANL. Details of the Test Assembly's mechanical systems are supplied in ANL Drawing No. R0408-0004-DE. Figure 3-2, which is a reduction copy of ANL Dwg. No. R0408-0004-DE (sheet 2), shows the cross sectional details of the test assembly.

As Figures 3-1 and 3-2 show, the basic structural assembly is about 86-ft. in overall height, and consists of a 52-in. by 12-in. rectangular entrance and heated duct system that expands to 52-in. by 18-in. above the heated section to the exit weather cap. The entire height of the test assembly above the entrance will be thermally insulated so that negligible heat loss will be experienced when the system is at thermal equilibrium. The mechanical system is composed of many subassemblies. The primary subassemblies, from the bottom to the top, are the entrance, the base support, the heated test section, the outlet ductwork including the 'S' flue, the forced-flow fan and butterfly damper system, the slide (flat plate) damper, and the exit stack and weather

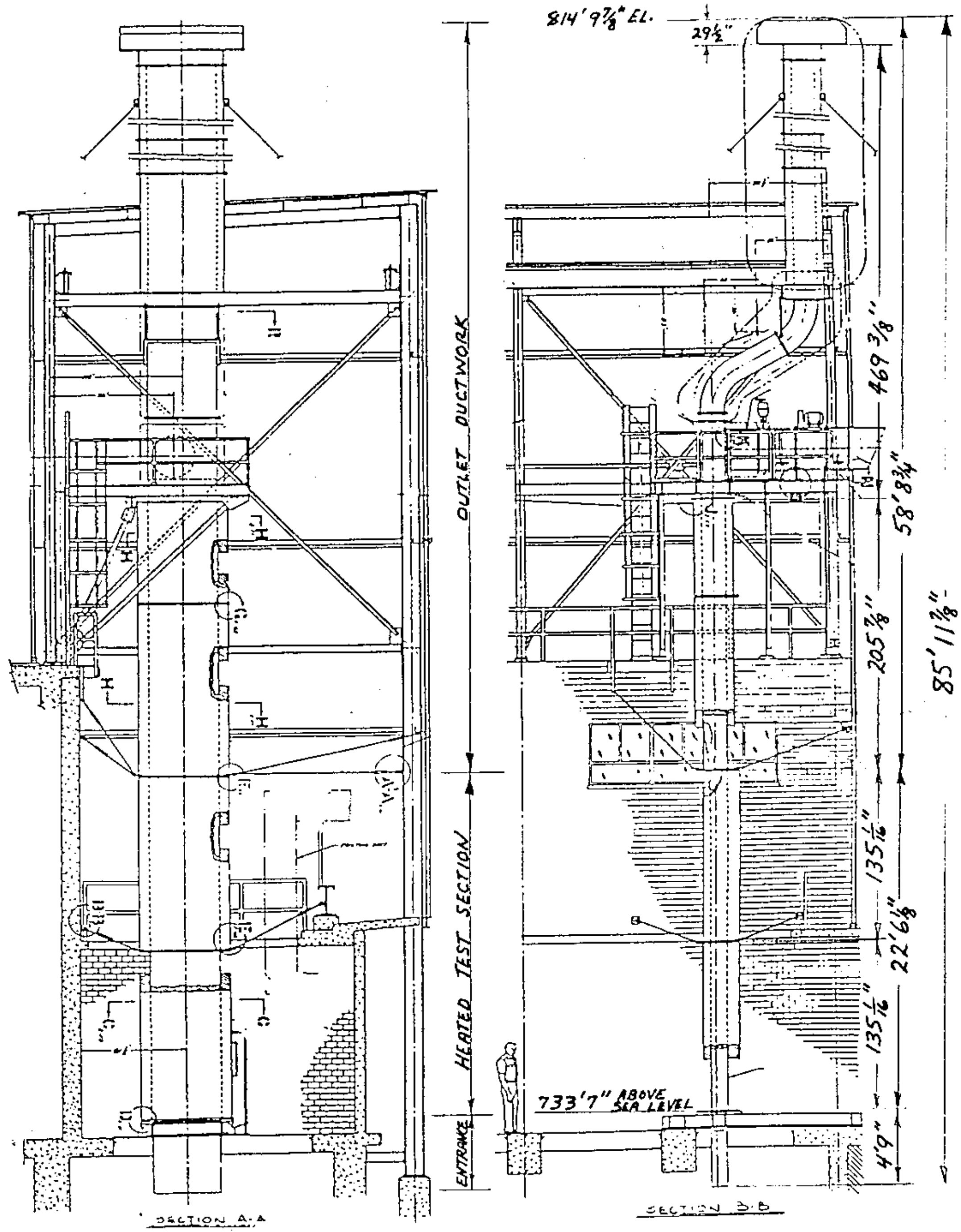


Figure 3-1. ANL Shutdown Heat Removal Test Assembly (Reduction of ANL Dwg. No. R0408-0004-DE, Sheet 1 of 4).

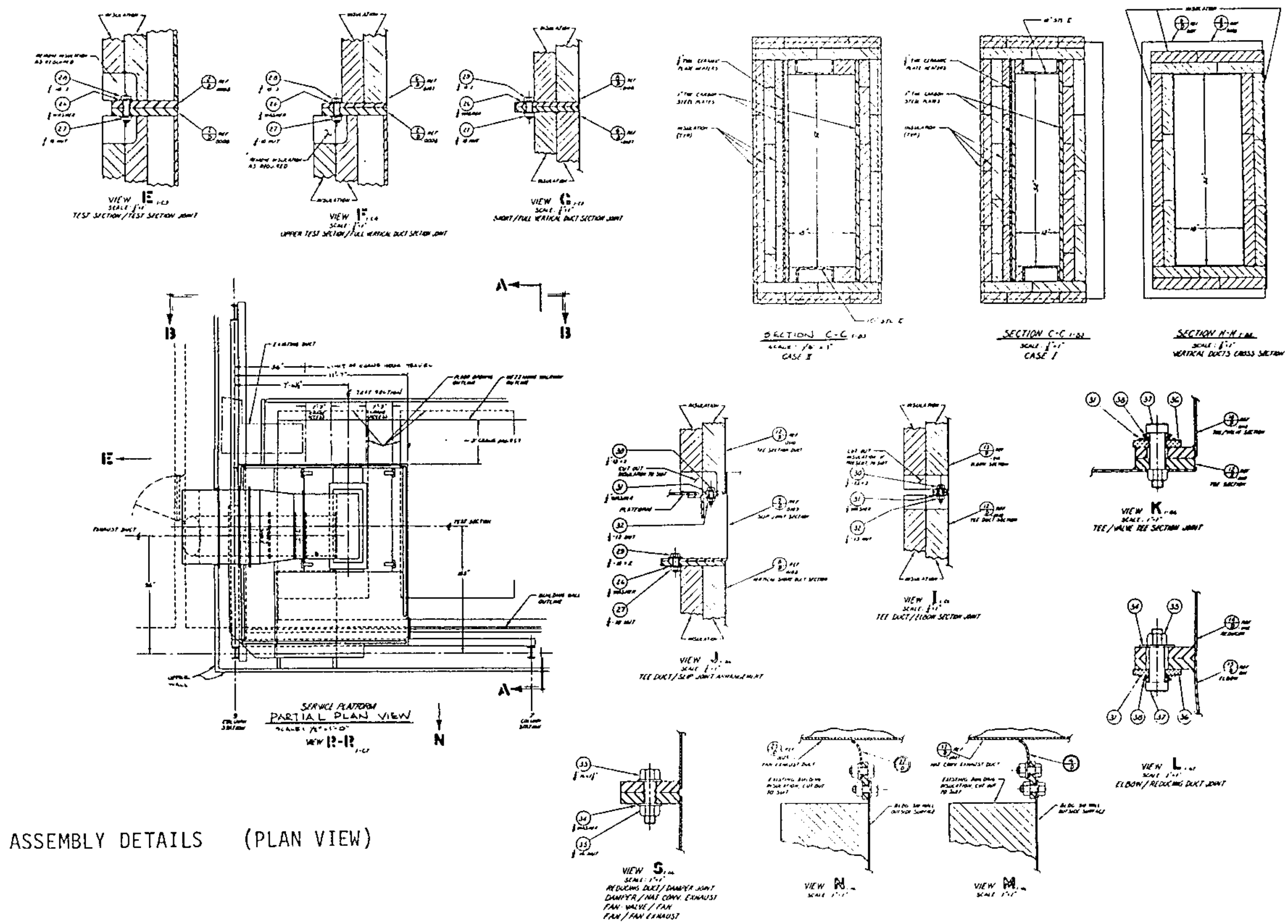


Figure 3-2. Assembly Details of the Test Assembly (Reduction of ANL Dwg. No. R0408-0004-DE, Sheet 2 of 4).

cap. Those subassemblies will be discussed more completely below in Sections 3.1.1 through 3.1.5.

3.1.1 Entrance

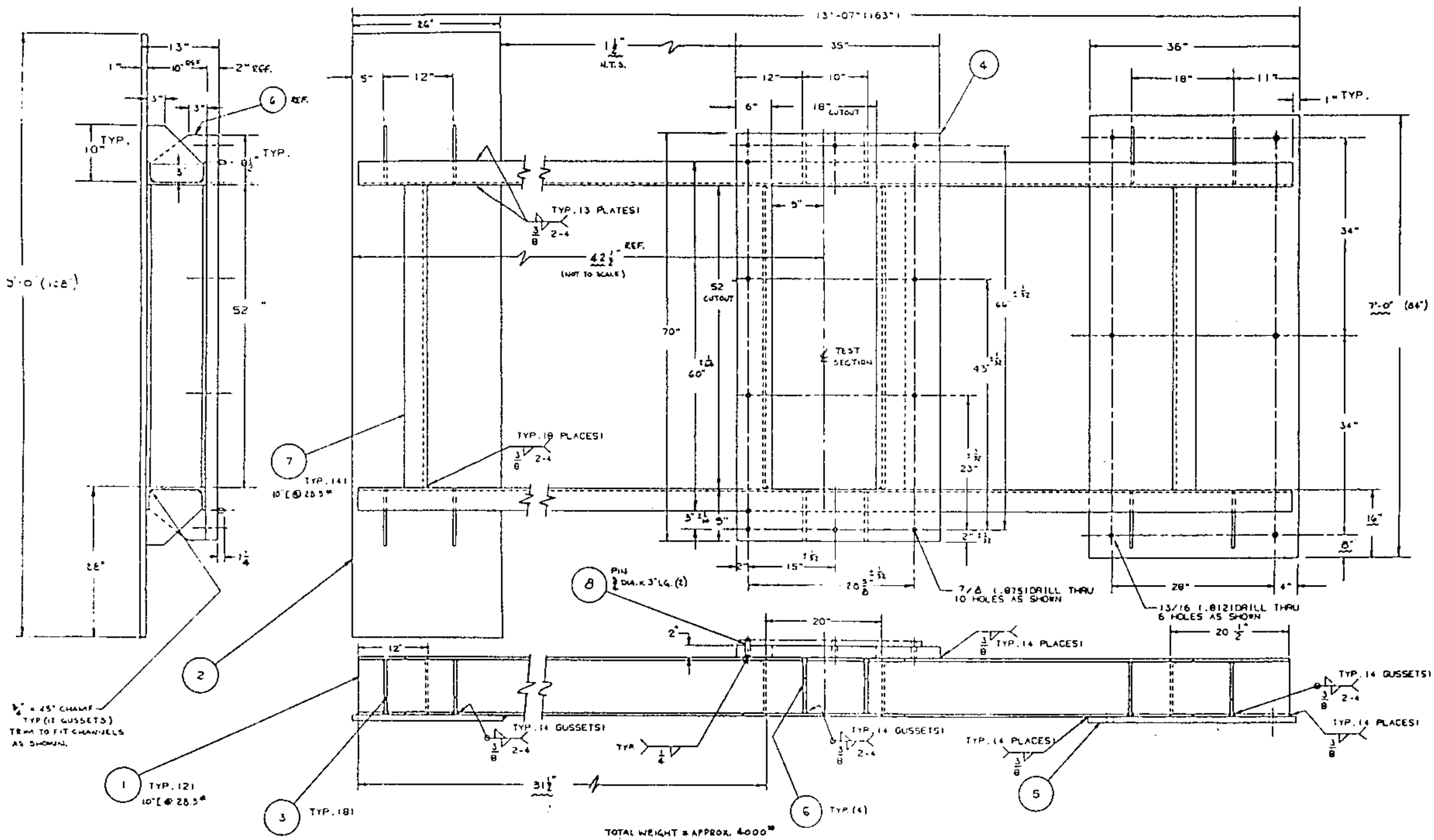
The geometric details of the inlet duct assembly are given in ANL Dwg. No. R0408-0024-DD. Its basic dimensions are 12-in. x 52-in. x 56.5-in. long. It is fabricated from 14-gauge (0.0747-in.) cold rolled steel (CRS) sheet stock, and steel angle plates for fastening. Its assembled weight is about 180 pounds.

The inlet duct will be instrumented for the measurement of inlet air temperature. Four port holes are provided for air temperature measurement using radiation-shielded thermocouple probes. The holes are located on the east side of the duct on a horizontal plane at about one hydraulic diameter (20-in.) from the bottom edge of the inlet duct. One hole is located at 6.5-in. from the north end, and one hole at 6.5-in. from the south end, the remaining two holes are located between those end holes at a distance of 13-in. apart.[20]

Details of the actual locations of the radiation-shielded air temperature TCs are supplied in Section 3.3.1.

3.1.2 Base Support

Fabrication details for the base support weldment are shown in Fig. 3-3, which is a reduced copy of ANL Dwg. No. R0408-0006-DD. The material used to fabricate the base support is ASTM A36 structural steel. The assembled weight of the base support is approximately 4000 pounds. Its function is to provide a stable support base for a 50-ft. test section having a design load of 40,000 lbs. concentrated on a fixed, simply supported beam at the point of maximum deflection. For an allowable deflection of 1/8-in., a beam having an inertial moment of I_{xx} = 113.4-in^4 is required, however, two beams are used, thus the required inertial moment rating for each beam is I_{xx} = 56.7-in^4. The two structural beams used for the base support are Bethlehem Steel Corp. special channel beams SC-10B (28.5 lbs/ft), which are each rated at having a minimum



BASE SUPPORT WELDMENT

Figure 3-3. The Base Support Weldment of the Test Assembly (Reduction of ANL Dwg. No. R0408-0006-DD).

I_{xx} = 125.5-in^4 for a total rating of 251-in^4. This is 2.22 times greater than required for the maximum design load conditions of 40,000 lbs. But the Test Assembly currently has a test section of about 22-ft. or about one-half the design load, therefore, the base support structural rating for the current as-built Test Assembly is 4.4 times greater than the minimum required.

3.1.3 Heated Test Section

The Heated test section is composed of two separate but very similar subassemblies. The lower subassembly is identified as Test Section No. 1 Subassembly (ANL Dwg. No. R0408-0008-DD), and the upper subassembly is identified as Test Section No. 2 Subassembly (ANL Dwg. No. R0408-0026-DD). The parts list for Test Sections Nos. 1 and 2 are respectively given in ANL PL/Nos. R0408-0008-PL and R0408-0026-PL. The basic configuration of the test section is shown in Figs. 3-4, and 3-5, and a detailed cross sectional view is shown in Fig. 3-6. Each of the two subassemblies are comprised of the following components:

1. The Back Plate (ANL Dwg. No. R0408-0106-DD), which is elsewhere referred to as the duct wall, and the Back Plate #1 and #2 Instrumentation Penetration Spec's (ANL Dwg. Nos. R0408-0133-DD and R0408-0134-DD) are a related set of components. The back plate is fabricated from SAE 1020 low carbon steel, which has stated ladle composition limits given as 0.18%/0.23% C, 0.30%/0.60% Mn, 0.040% P_{max}, 0.50% S_{max}, and Fe being the remaining constituent.[20] The surface condition of the back plate is "mill scale" oxidized so that its emissivity should be initially in the 0.7 to 0.9 range. The plates were individually inspected and chosen for use based on the uniformity and nature of the surface condition, which had a thin surface scale that was an electrically nonconducting oxide with a dull dark-purple coloration. Surface deformation by grinding for welding and thermocouple spot welding was kept at a minimum.

2. The Mounting Plate (ANL Dwg. No. R0408-0101-DD), which is elsewhere referred to as the heated or guard vessel wall, is described in the drawing shown in Fig. 3-8. There are two mounting plate instrumentation penetration spec's identified as No. 1 and No. 2; they are described respectively in ANL

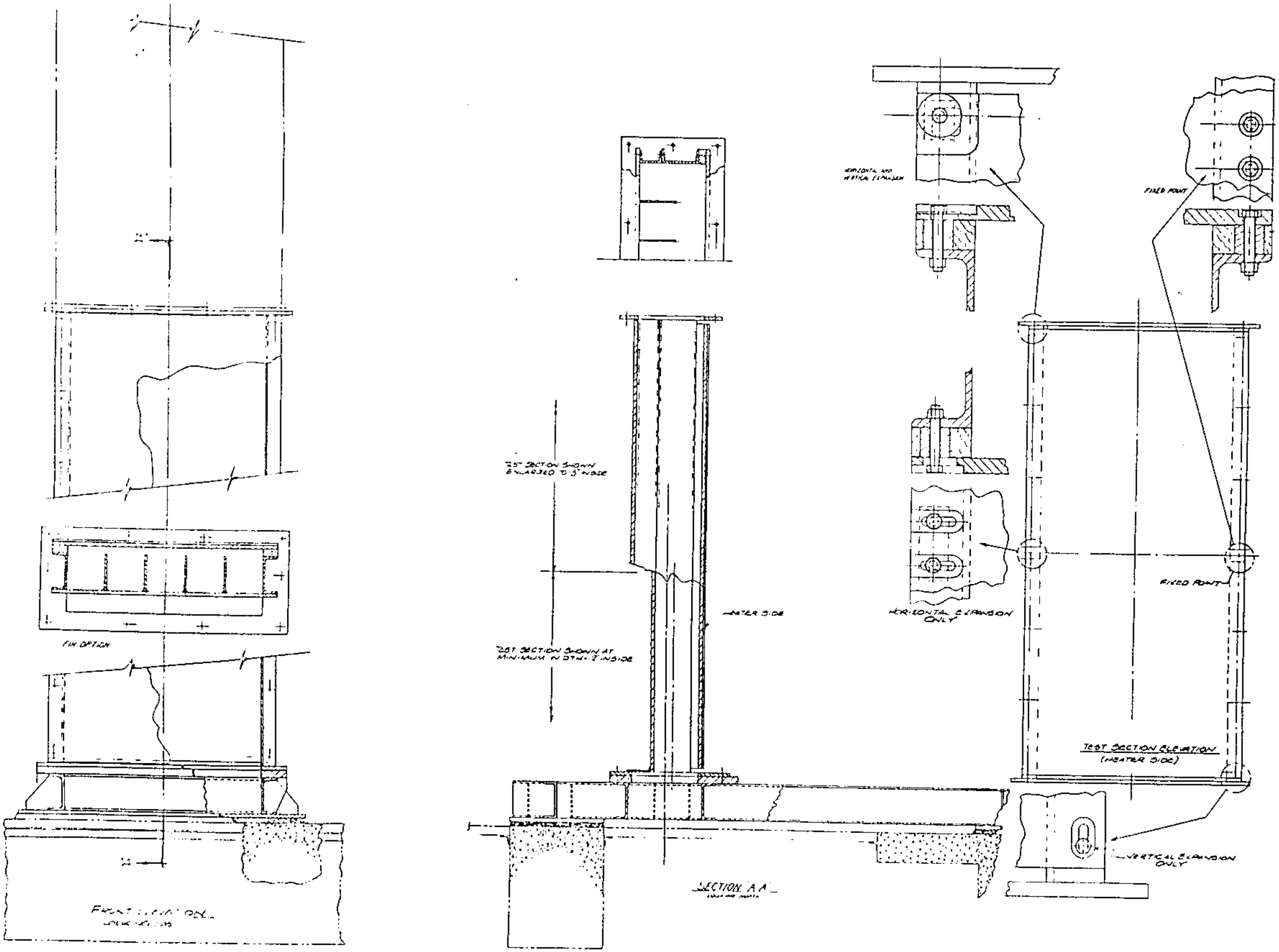
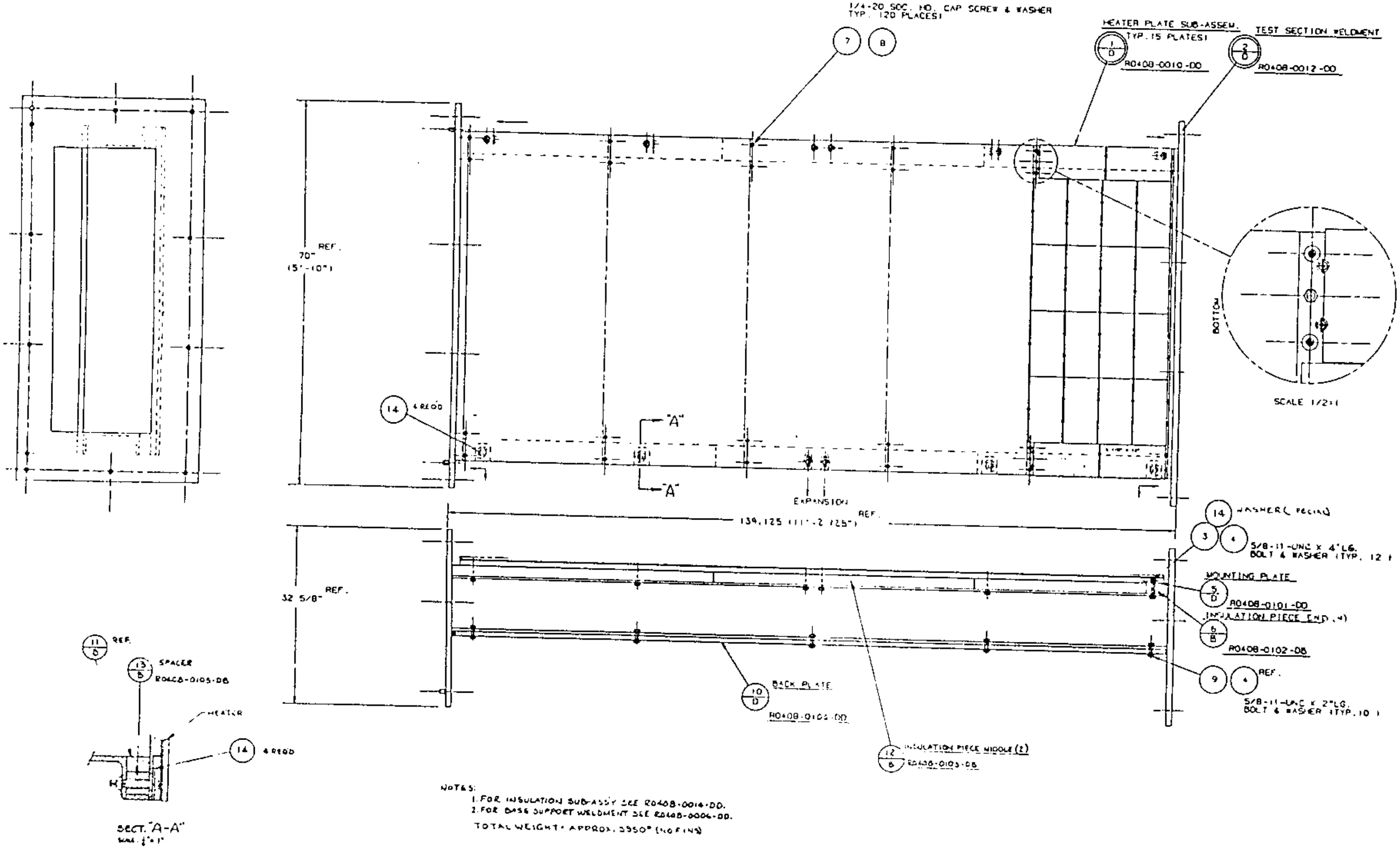


Figure 3-4. Test Section Layout (Fins on Duct Wall Not Included in Current Design).



TEST SECTION SUBASSEMBLY

Figure 3-5. Test Section Subassembly (Reduction of ANL Dwg. No. R0408-0008-DD).

SHUTDOWN HEAT REMOVAL TEST ASSEMBLY

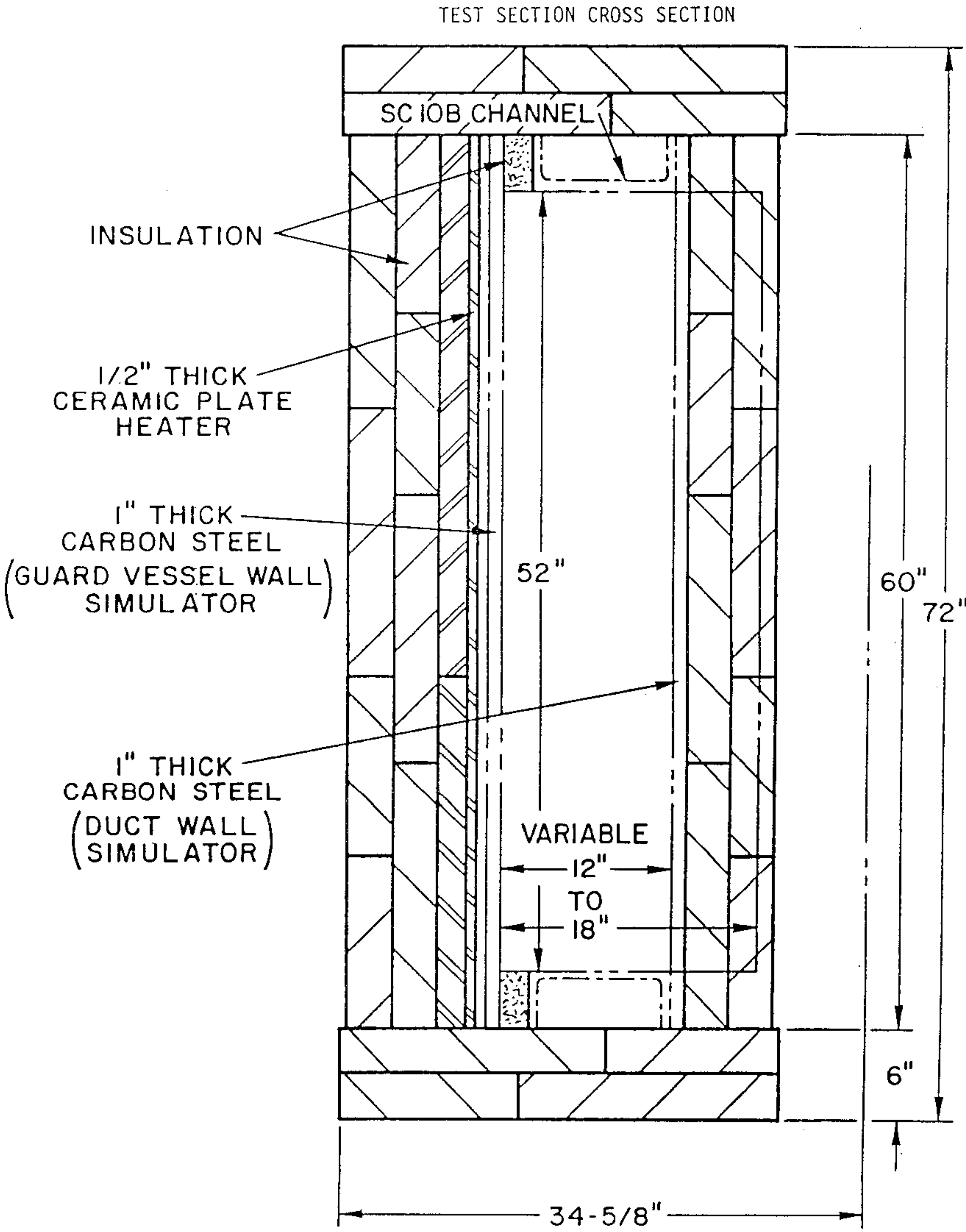
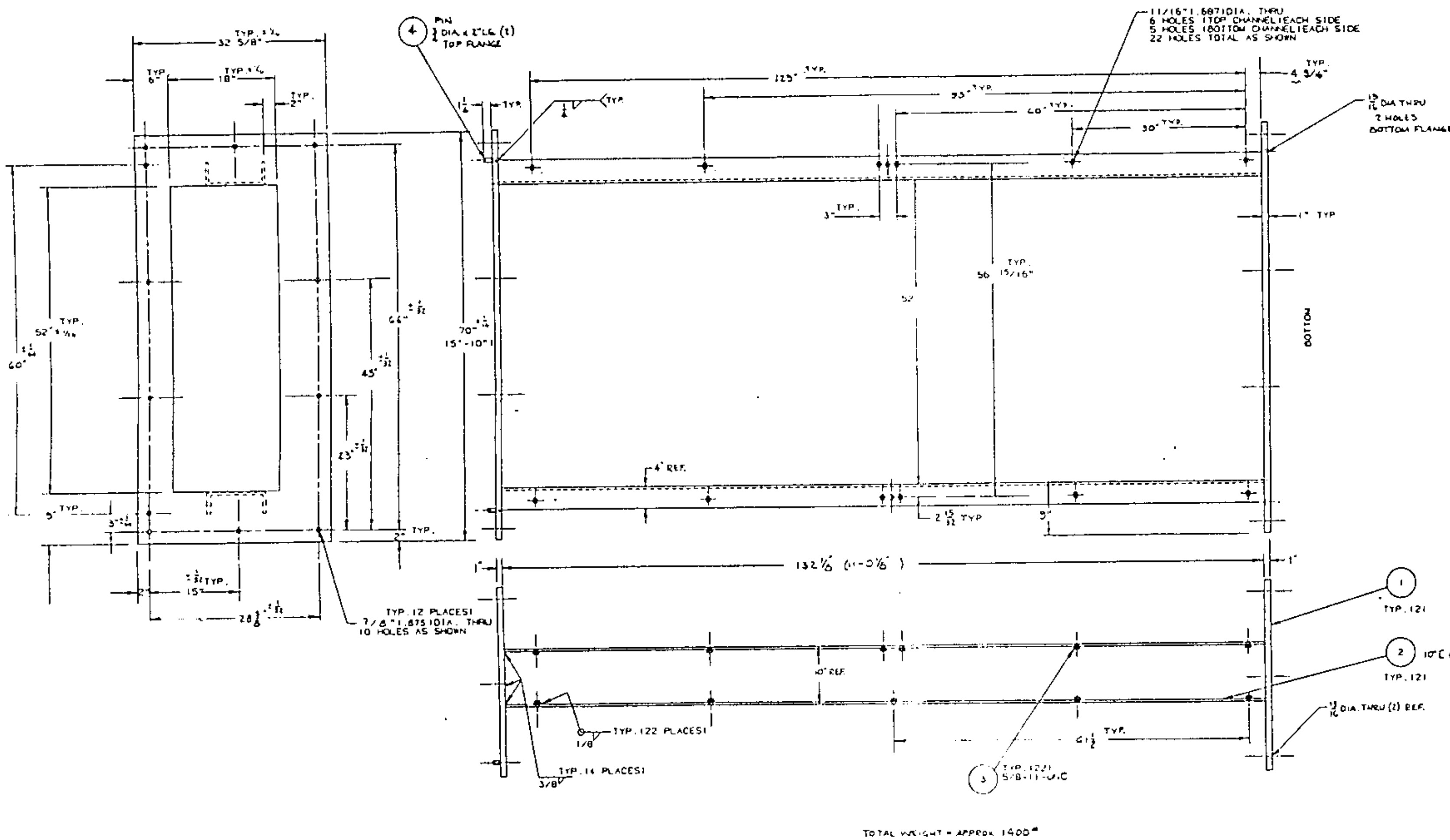


Figure 3-6. Test Section Cross-Sectional Description.

Dwg. Nos. R0408-0131-DD, and R0408-0132-DD. The mounting plates are fabricated from the same material as the back plates, they are of the same chemical composition, and have similar surface conditions. As is shown in Fig. 3-8, the mounting plate has enlarged mounting holes machined in it to allow for thermal expansion in all directions. Also, as can be seen in Figs. 3-5, and 3-8, the heater plate subassembly is attached or "hung" to the mounting plate in two locations so that the heater plate subassembly is allowed to expand horizontally and vertically downward from the points of attachment to the mounting plate.

3. The Test Section Weldment (ANL Dwg. No. R0408-0012-DD) is the vertical support assembly to which the mounting plate and back plate are attached. Figure 3-7 shows the structural layout of the test section weldment. The 22-ft. vertical height of the test section is comprised of two identical test section weldment subassemblies each consisting of two ASTM A36, SC-10B, low carbon, structural steel, 10-in. x 4-in. x 132.5-in. channels that are welded at each end to a flange (1-in. x 32.625-in. x 70-in.) which has an opening of 52-in. by 18-in. The test section weldments have essentially the same chemical composition as the back plates and mounting plates, and the surface condition is very similar.

4. The Heater Plate Subassembly (ANL Dwg. No. R0408-0010-DD), which consists of a stainless steel sheet (1/8-in. x 2-ft. x 5-ft.) to which twenty ceramic plate electric heaters are attached, is shown in Fig. 3-9. The stainless steel sheets were sandblasted, and then heat treated to 1900°F to relieve internal and surface stresses. The sandblasting process was performed to enhance the surface emissivity of the sheets from about 0.25 to about 0.90 uniformly over both sides of the sheets, which should significantly improve heat transfer and provide a more uniform temperature distribution, and thereby reduce the chance of warpage of the stainless steel sheet.[21,22] Figure 3-9 shows that the ceramic plate heating elements are fastened to the steel sheet with 10-32 size studs that are welded to the steel sheets. Each heater subassembly contains twenty ceramic plate electric heater elements (~ 6-in. x 12-in.). The 16 central heater elements are one heater zone, and the four edge heater elements compose the second heater zone on the 2-ft. x 5-ft. heater plate subassembly.



TEST SECTION WELDMENT

Figure 3-7. Test Section Weldment (Reduction of ANL Dwg. No. R0408-0012-DD).

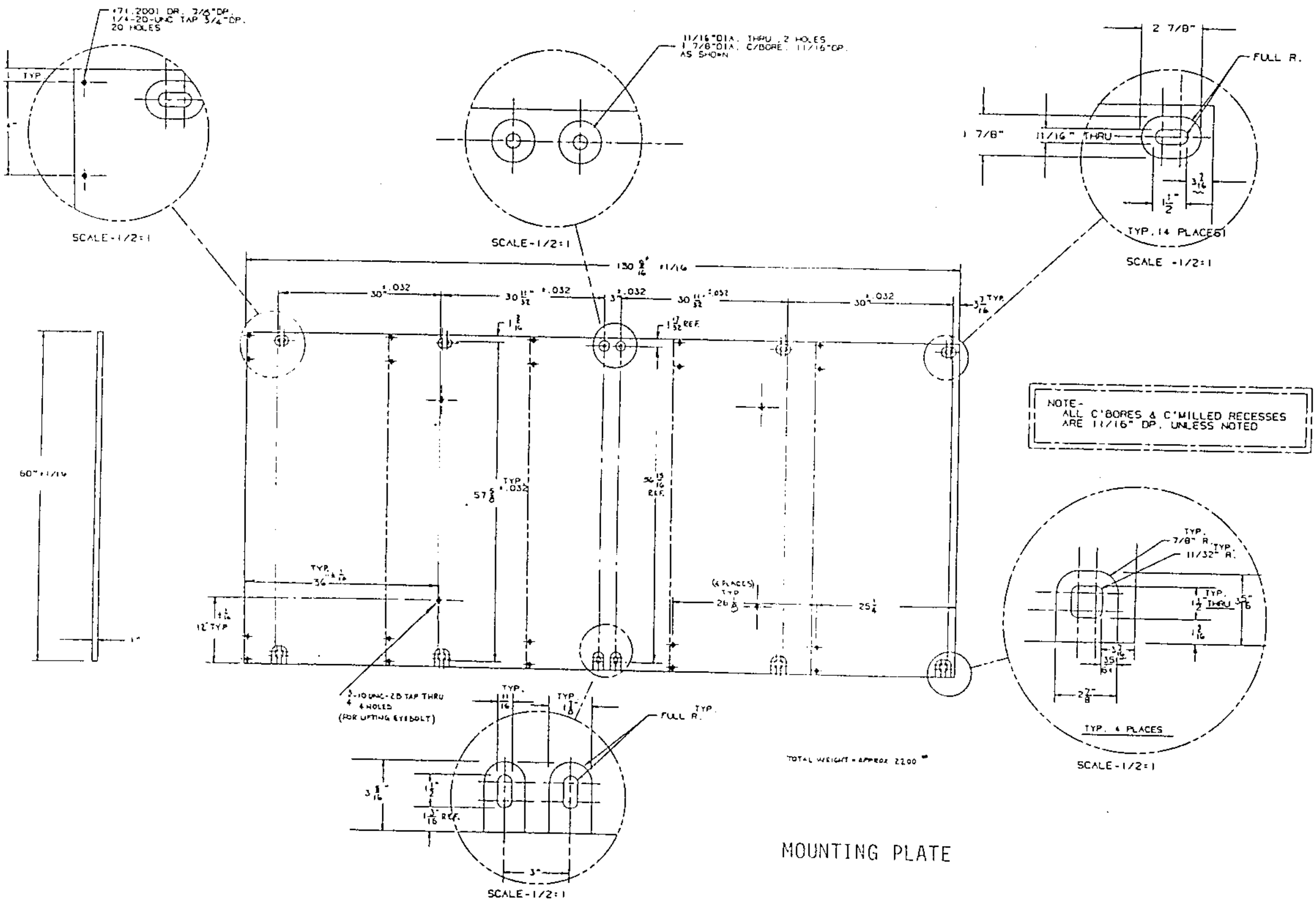


Figure 3-8. Test Section Mounting Plate (Reduction of ANL Dwg. No. R0408-0101-DD).

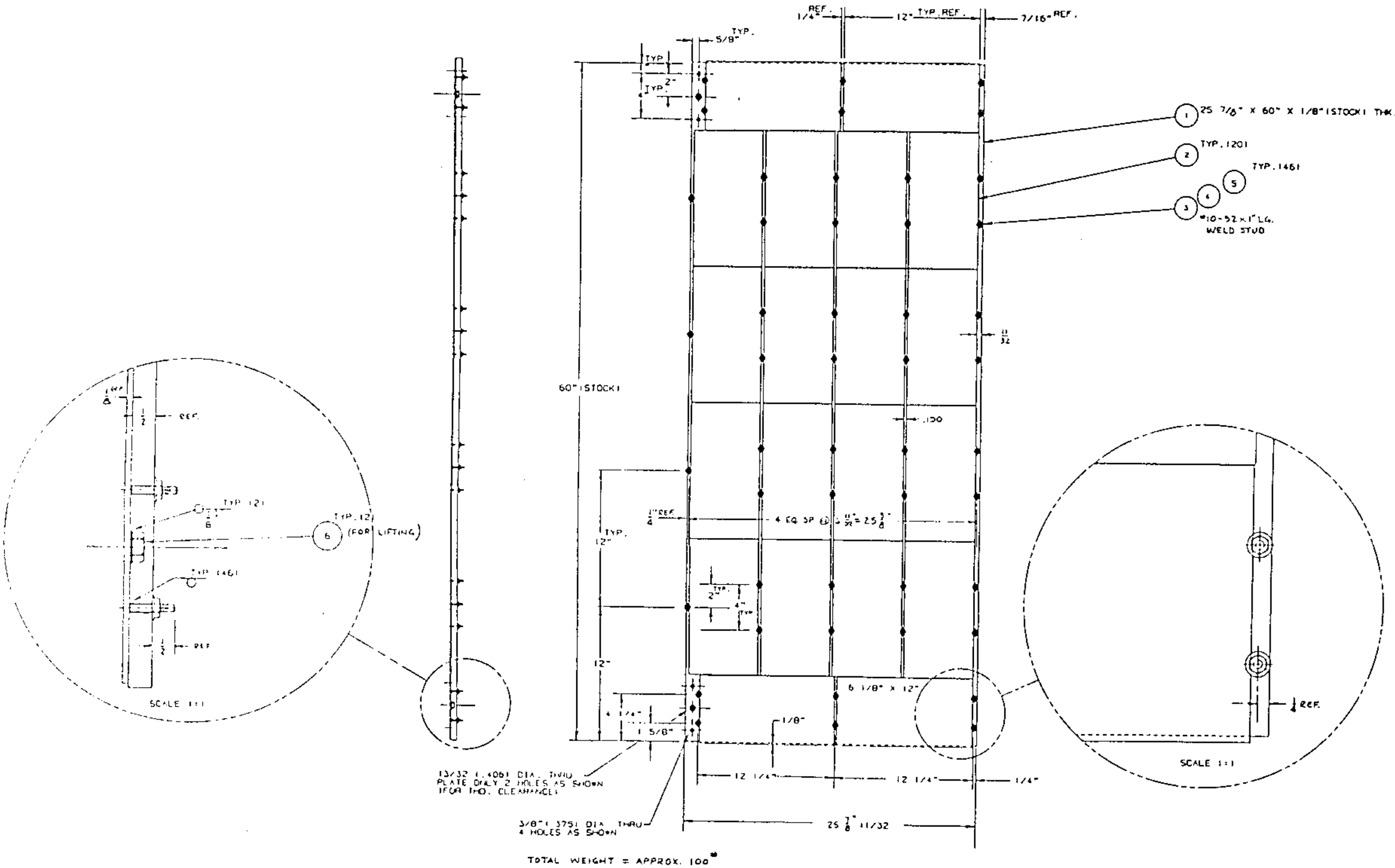


Figure 3-9. Test Section Heater Plate Subassembly (Reduction of ANL Dwg. No. R0408-0010-DD).

5. The Insulation Subassembly (ANL Dwg. No. R0408-0014-DD), which consists of blocks of overlaid insulation surrounding the test section in a pattern that should help to seal the test section from air in or out leakage is shown in Fig. 3-10. From the enlarged cross sectional view shown in Fig. 3-11 it is seen that a 2-in. thick, high temperature (2300°F), high density, ceramic fiber insulation board[23] is located next to the heater assembly, and between the side channel beams and the mounting plate. The chemical composition of the ceramic fiber board is 50% Al_2O_3, and 50% SiO_2, the nominal density is 16.5 lbs/ft^3, and the thermal conductivity is approximately linear from a value of 0.38 at 500°F to 0.95 Btu/ft^2/hr/°F/in. at 1500°F. This and other pertinent information about the RPC-X ceramic fiber board is given in Table 3-1. The remaining peripheral insulation consists of Johns Manville Thermo-12 block insulation, which is a hydrous calcium silicate insulation material molded into 3-in. thick x 18-in. x 36-in. blocks that are overlaid to provide 6-in. of insulation. The Thermo-12 insulation has a maximum service temperature rating of 1500°F, and its thermal conductivity is reasonably linear from a value of 0.38 at 100°F to 0.86 Btu-in./ft^2/°F/hr at 1000°F. This and other information about the calcium silicate insulation is given in Table 3-2. With reference to Fig. 3-11 it is shown that there is a total of 6-in. of insulation surrounding the test section on three sides, and 8-in. of insulation on the heater side.

3.1.4 Outlet Ductwork and Exhaust Hood

The outlet ductwork consists of the Vertical Full Duct Section (ANL Dwg. No. R0408-0107-DD), the Vertical Short Section (ANL Dwg. No. R0408-0108-DD), the Slip Joint Section (ANL Dwg. No. R0408-0109-DD), the Tee Duct Section (ANL Dwg. No. R0408-0110-DD), the Ducting Support (ANL Dwg. No. R0408-0019-DD), the Valve/Tee Duct Section (ANL Dwg. No. R0408-0114-DD), the Fan Exhaust Duct (ANL Dwg. No. R0408-0023-DD), the Exhaust Stack Support (ANL Dwg. No. R0408-0029-DD), the Intermediate Chimney Duct (ANL Dwg. No. R0408-0162-DD), and the Top Chimney Duct (ANL Dwg. No. R0408-0166-DE). The exhaust hood is a commercially obtained hood or weather cap, which has a head loss coefficient (K) rating of about 0.5 at 5-ft/s to about 1.0 at a flow of 20-ft/s as determined from data supplied by the manufacturer.[24,25]

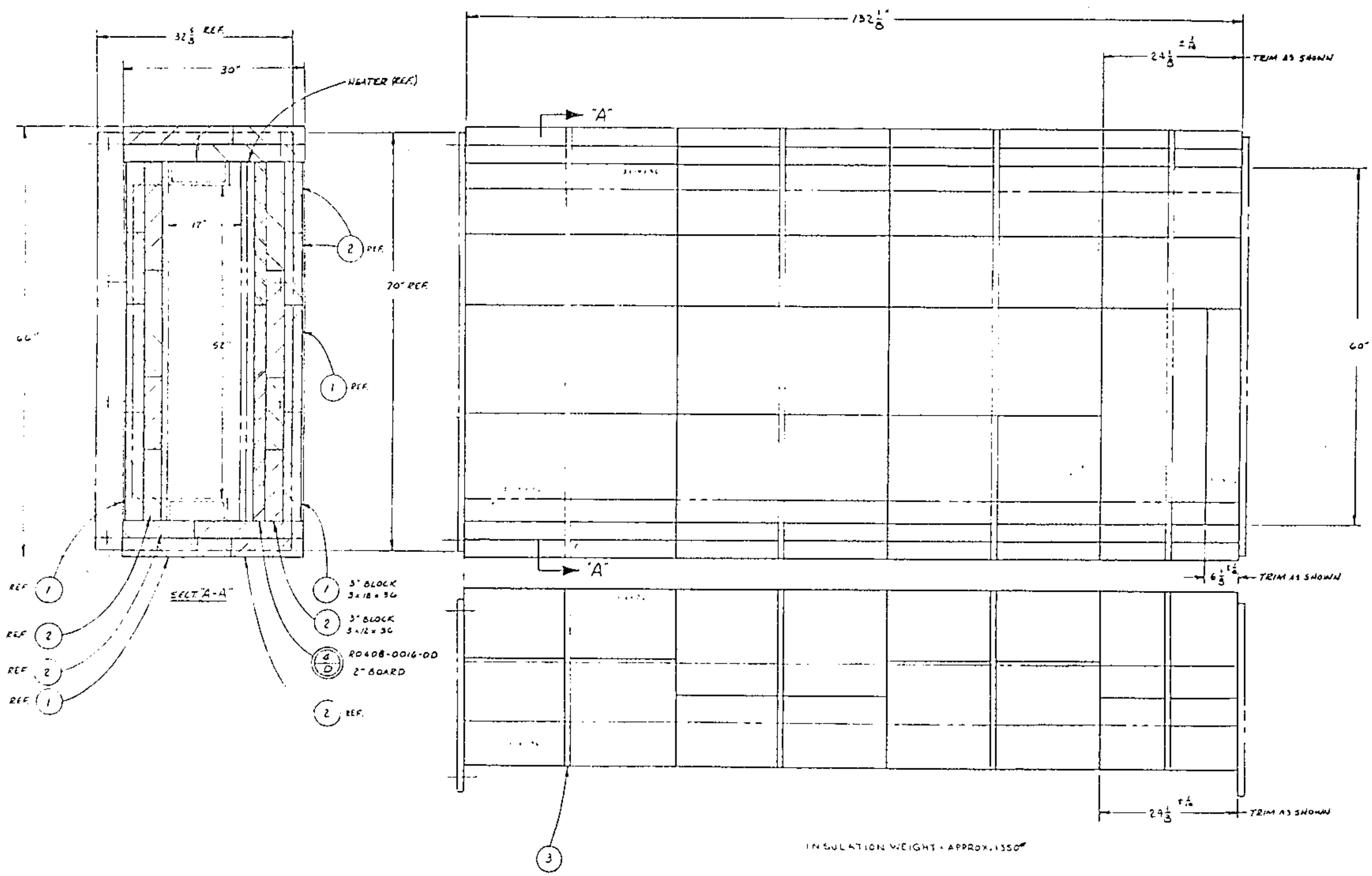


Figure 3-10. Test Section Insulation Subassembly (Reduction of ANL Dwg. No. R0408-0014-DD).

Ref: Dwg. No. R0408-0014-DD

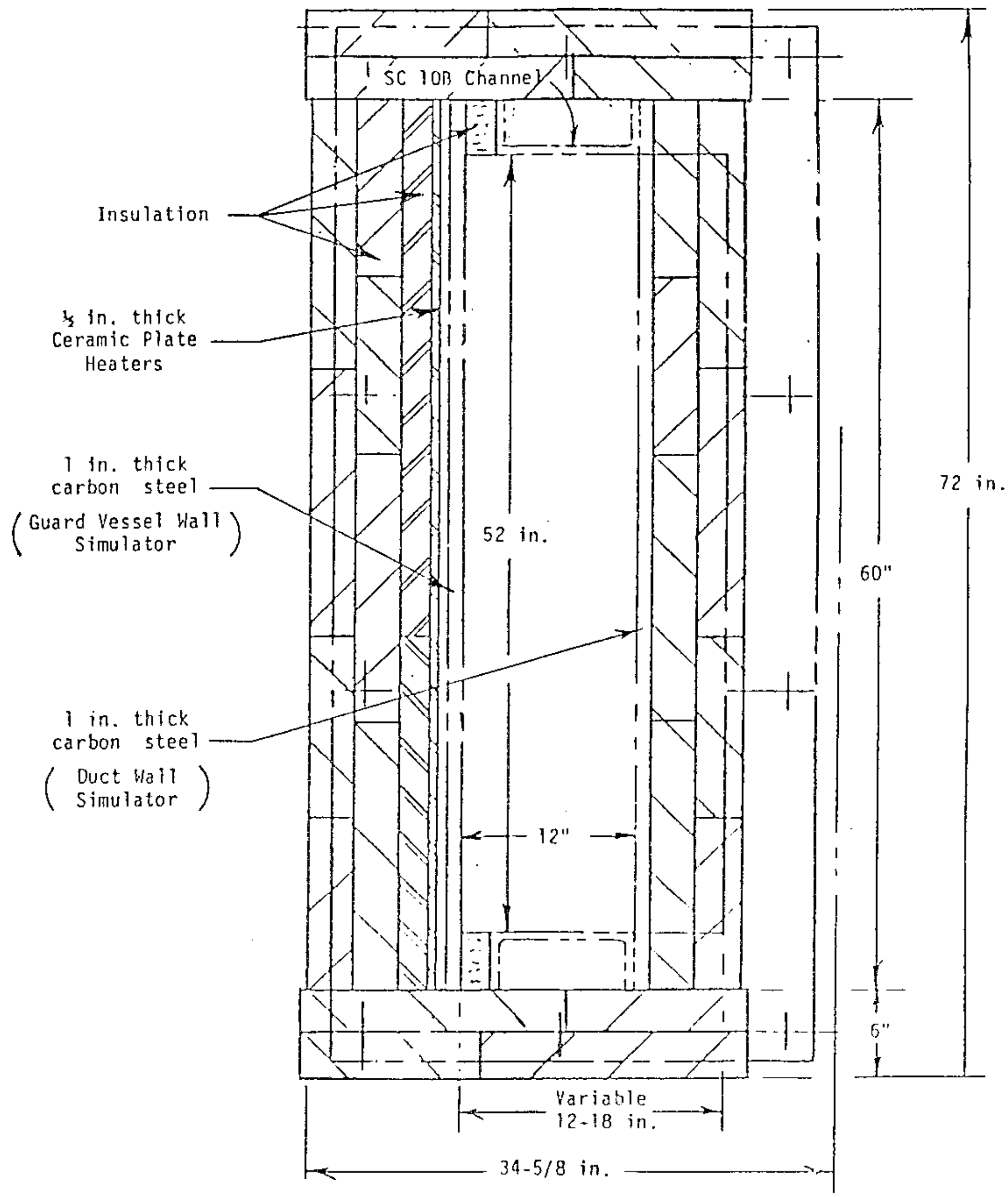


Figure 3-11. Cross-Sectional View of the Test Section/Insulation Subassembly.

Table 3-1. RPC-X Ceramic Fiber Board Insulation Technical Data

Temperature Limit		2300°F
Fiber Chemistry		50% Al_2O_3 50% SiO_2
Density		15-18 lbs/ft^3
Emissivity		0.85
Specific Heat		0.27 BTU/lbm-°F
Compressive Strength		1200 lbs/ft^2
Rupture Modulus		60 psi
Linear Shrinkage after 24-hrs at:		
	800°F	2.3%
	2000°F	2.9%
	2200°F	3.6%
Thermal conductivity (Btu-in./ft^2/hr/°F) at temperature of:		
	500°F	0.38
	1000°F	0.64
	1500°F	0.95

Table 3-2. Johns Manville Thermo-12 Insulation Technical Data

Composition	Hydrous Calcium Silicate
Temperature Limit	1500°F
Density	13 lbs/ft^3
Compressive Strength	200 psi to produce 5% compression for 1.5-in. thick block
Linear Shrinkage	1.1% after 24-hr. at 1200°F

Thermal Conductivity (Btu-in./ft^2/°F/hr) at temperatures of:

100°F	0.38
300°F	0.44
500°F	0.48
700°F	0.65
900°F	0.78
1000°F	0.86

The vertical full duct section is fabricated from 14-gauge (0.0747-in.) cold rolled steel (CRS), and has 5/8-in. thick end flanges which are fabricated from hot rolled structural steel plate material (HRP). Its inside dimensions are 18-in. x 52-in., and it is 135-in. flange-to-flange in overall length. The cross-sectional transition from 12-in. x 52-in. to 18-in. x 52-in. is made within the vertical full duct section. The transition is accomplished with the triangular flow guide (ANL Dwg. No. R0408-0145-DD), which is shown in Fig. 3-12.

The vertical short duct has the same 18-in. x 52-in. rectangular dimension, and is 71-in. nominally in overall length. The short duct is fabricated from the same 14-gauge CRS material, and 5/8-in. thick HRP flange material. All the the duct sections are similarly fabricated from the same 14-gauge CRS material, and either 5/8-in. or 1/2-in. thick HRP material for the flanges. All the ductwork is insulated with a total of 6-in. of overlaid 3-in. thick Johns Manville Thermo-12 block insulation material except the horizontal exhaust fan ductwork. The external chimney ductwork is constructed of similar material, and it has differential expansion capability between the inner duct and the outer shroud. It additionally has steel corner supports (4"x4"x3/8" steel angle material) to which 14-gauge CRS sheet steel is welded to form a protective envelope over the insulated exterior chimney.

The weather hood is fabricated from galvanized steel sheet, and has a 30-in. x 64-in. interior-sized throat opening, which expands about 200% to a free area exit opening (Ref. 24).

3.1.5 Service Platform, Fan, Butterfly and Slide Dampers

The design details of the service platform for the Test Assembly are supplied in ANL Doc. No. R0408-1004-SE, dated Dec. 18, 1985.[26] That document contains information about design details including drawings, notes, and calculations, purchase requisitions, construction specifications and contracts. The service platform provides support and access for the fan, butterfly, and slide (flat plate) damper system. An overview of the platform region of the test assembly is shown in Fig. 3-13, which indicates the locations of the fan,

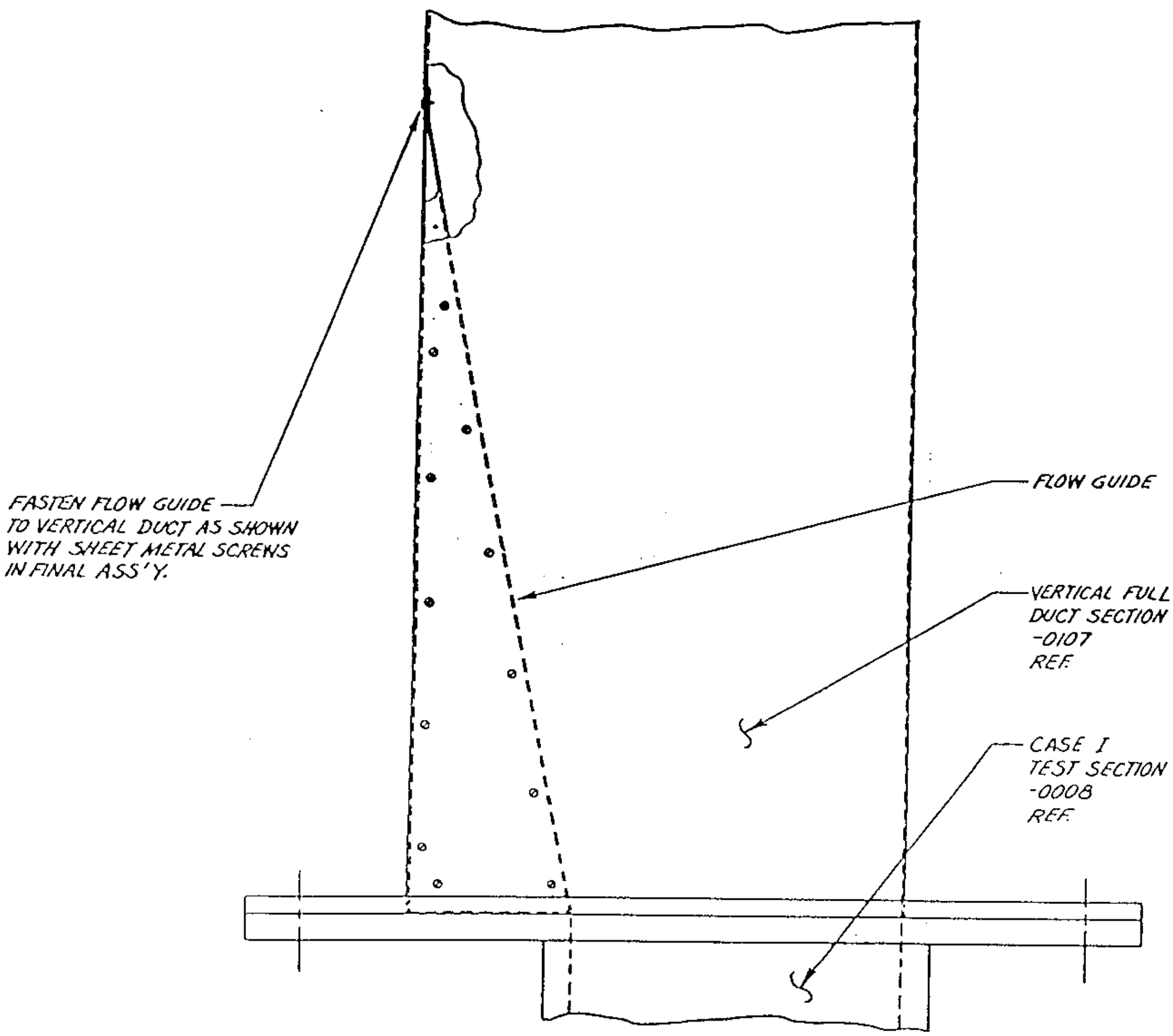
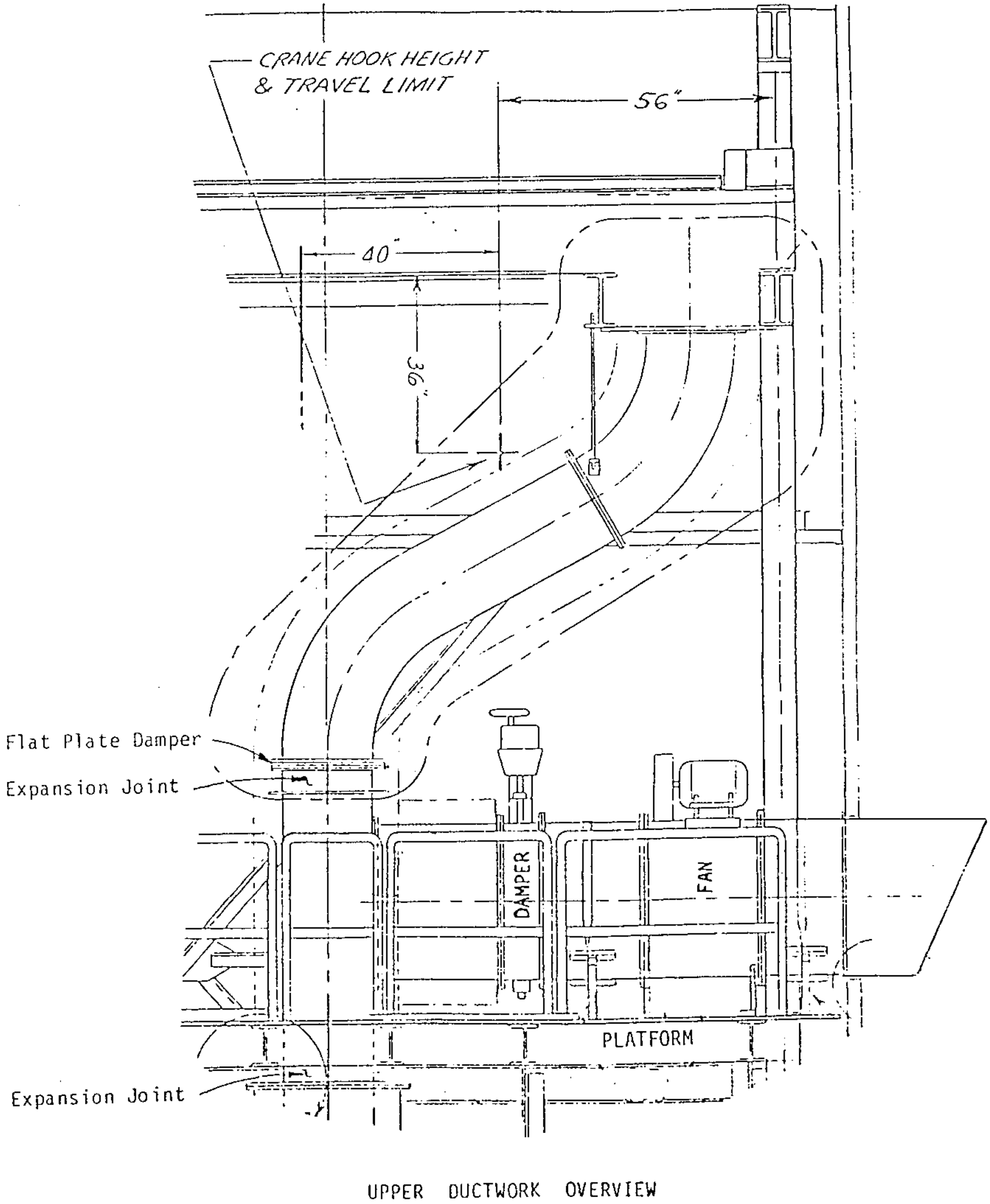


Figure 3-12. Triangular Flow Guide Inside the Vertical Full Duct Section (ANL Dwg. No. R0408-0145-DD).



UPPER DUCTWORK OVERVIEW

Figure 3-13. Overview of Platform, Fan, and "S" Flue Ductwork.

butterfly damper, flat-plate damper, and expansion joints, as well as the "S" flue ductwork, and the service platform. The lower expansion joint, which as shown in Fig. 3-13 is located contiguously below the Tee Section duct, is provided to accommodate the vertical thermal expansion of the test assembly between that point and the base support ~ 41 ft. below. The expansion joint located immediately above the Tee Section duct provides the capacity for both vertical and horizontal thermal expansion of the upper "S flue" ductwork.

Information about the fan, and the and butterfly dampers is supplied in ANL Doc. No. R0408-1002-DU dated August 1985. The fan is an Industrial Air, series 040, model 046B, slow speed, induced draft, tube-axial fan, which has a 500°F temperature rating, and produces a full flow of 17,000 CFM at 1200 RPM. The motor for the fan is a Reliance Electric, Model P18G3338, sealed enclosure, 230/460 volt, 3-phase, 5-HP, design B, class F insulation, 1800 RPM, energy efficient motor, which is capable of reversible, variable speed operation. The butterfly damper is a Control Equipment Co. 32-in. diameter butterfly damper with a 500°F temperature rating and 99% shutoff capacity. It can be manually operated or remotely operated by a Raymond Control System electric actuator (RCS Model MAR-100-30), which is incorporated into the system.

3.2 Electrical Systems

The electrical systems for the Test Assembly are the heater power and control system, and the auxiliary/instrumentation power and control system. Those systems are discussed in in Sections 3.2.1 and 3.2.2 below.

3.2.1 Heater Power and Control System

The heater power and control system design is shown in Fig. 3-14. Heater resistances have been measured to provide input data for on-line calculation of "local" power (heat flux) during experiments (E^2/R x SCR on-time). Figure 3-15 shows a typical 2-ft. x 5-ft. heater subassembly ready for fastening to the test section mounting plate (guard vessel wall). There are five such heater subassemblies mounted to each 11-ft. test section for a total of ten for a 22-ft. test section. Each heater subassembly contains twenty ceramic

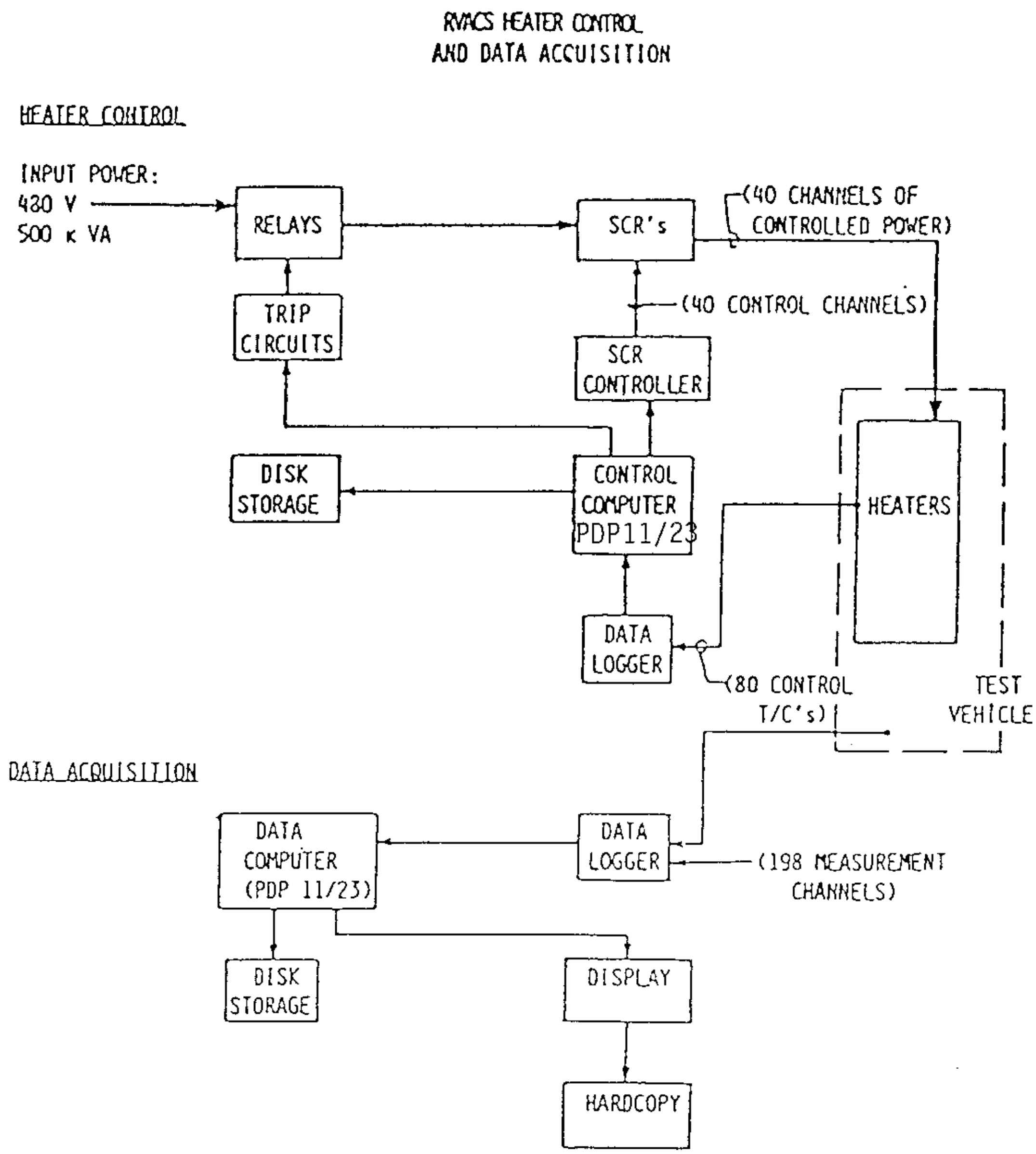


Figure 3-14. RVACS/RACS Heater Control and Data Acquisition System Block Diagram.

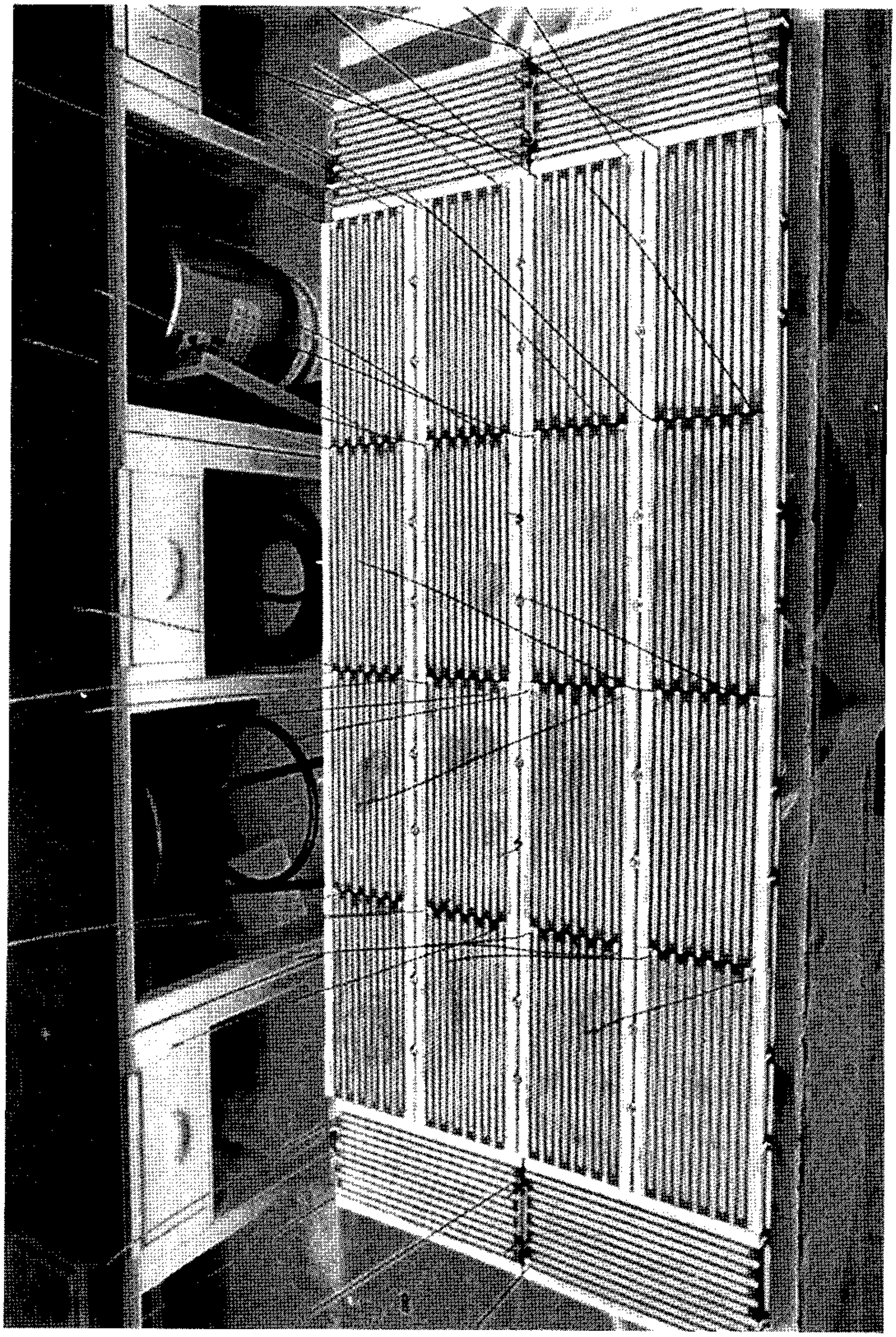


Figure 3-15. Photograph of a Heater Plate Subassembly.

plate electric heater elements; the 16 central heater elements constitutes one heater zone, and the four edge heater elements, referred to as the guard heater elements, composes the second heater zone within the 2-ft. by 5-ft. subassembly. Each of the heater zones for each of the ten subassemblies are individually computer controlled. Figure 3-16 is a close-up picture of a heater subassembly, which shows more clearly the details of the twisted, double-wire heater leads, and the control-thermocouple locating studs.

With reference to Fig. 3-15, the heater elements are series wired in strings of four, and each heater-string is parallel wired to a 480-V power supply so that each heater element will operate at 120-V. The design limits of the Mellon Co., Model 12F-997, flat, ceramic plate heaters are 2200°F, and 1100-Watts per 6-in. x 12-in. heater plate, thus, they have a 2.2 kw/ft^2 heat flux capability.[27] This is substantially more power than will be required for testing; the highest constant temperature test planned is at 1000°F, and the highest constant heat flux test planned is at 1.5 kw/ft^2. In any event, the heater over-temperature limit will be computer controlled so that the temperature near the heater elements does not exceed 1600°F.

3.2.2 Auxiliary/Instrumentation Power and Control

In addition to heater power several other system components require 110 V service, they are as follows:

- General service power (lighting, power hand tools and equipment).
- Variable speed, reversible fan and damper control power.
- Control console and instrument power (Figs. 3-17, and 3-18).
- On-line computer control and DAS system (Figs. 3-17, and 3-18).

Figure 3-17 is a picture the control console and communication terminal, and Fig. 3-18 illustrates the general location of the various power and instrumentation control units located in the control console. Table 3-3 contains a list of all those units.

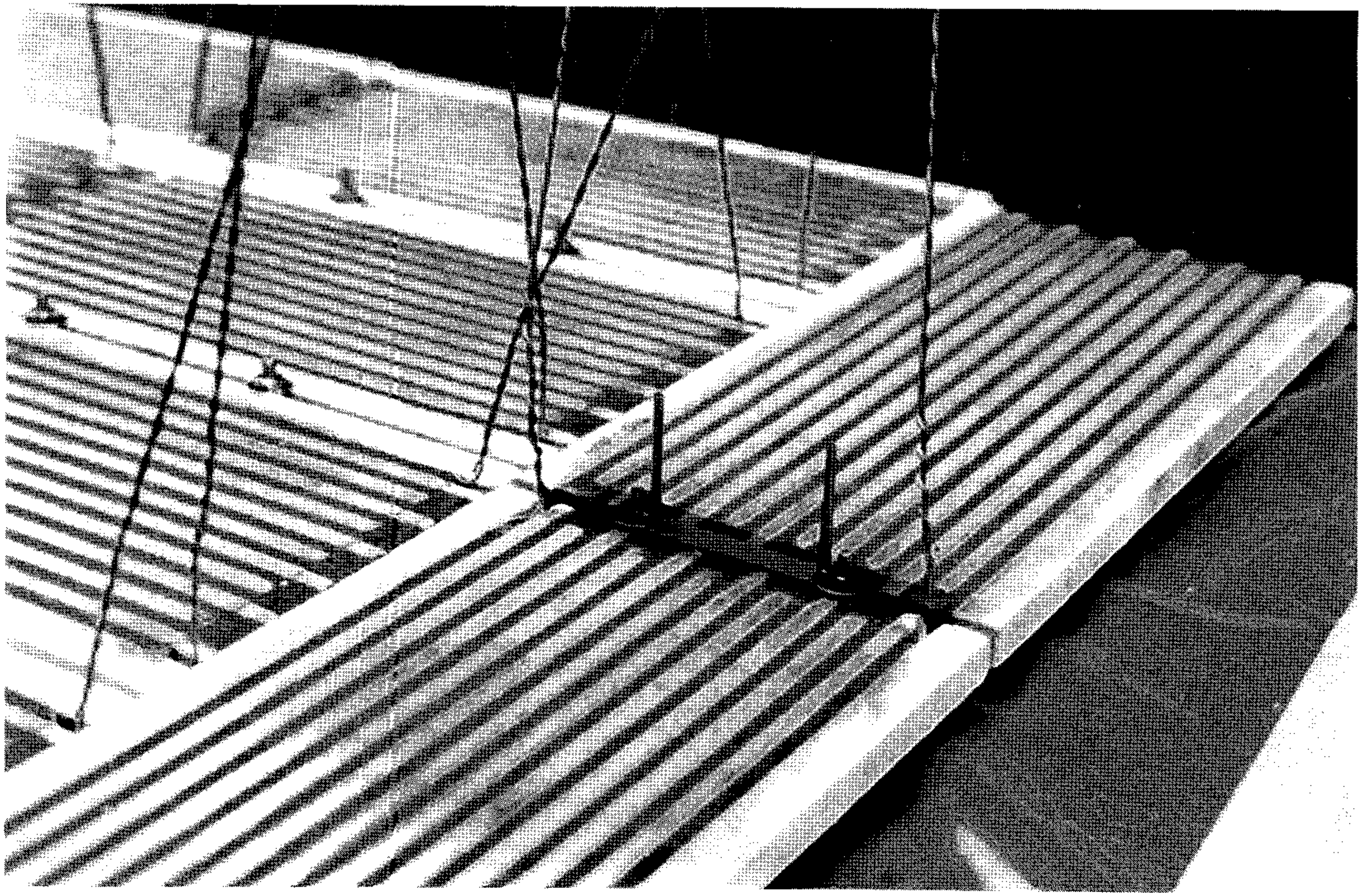


Figure 3-16. Close-up View of a Heater Plate Subassembly Showing Thermocouple Support Studs and Twisted Double-Wire Heater Leads.

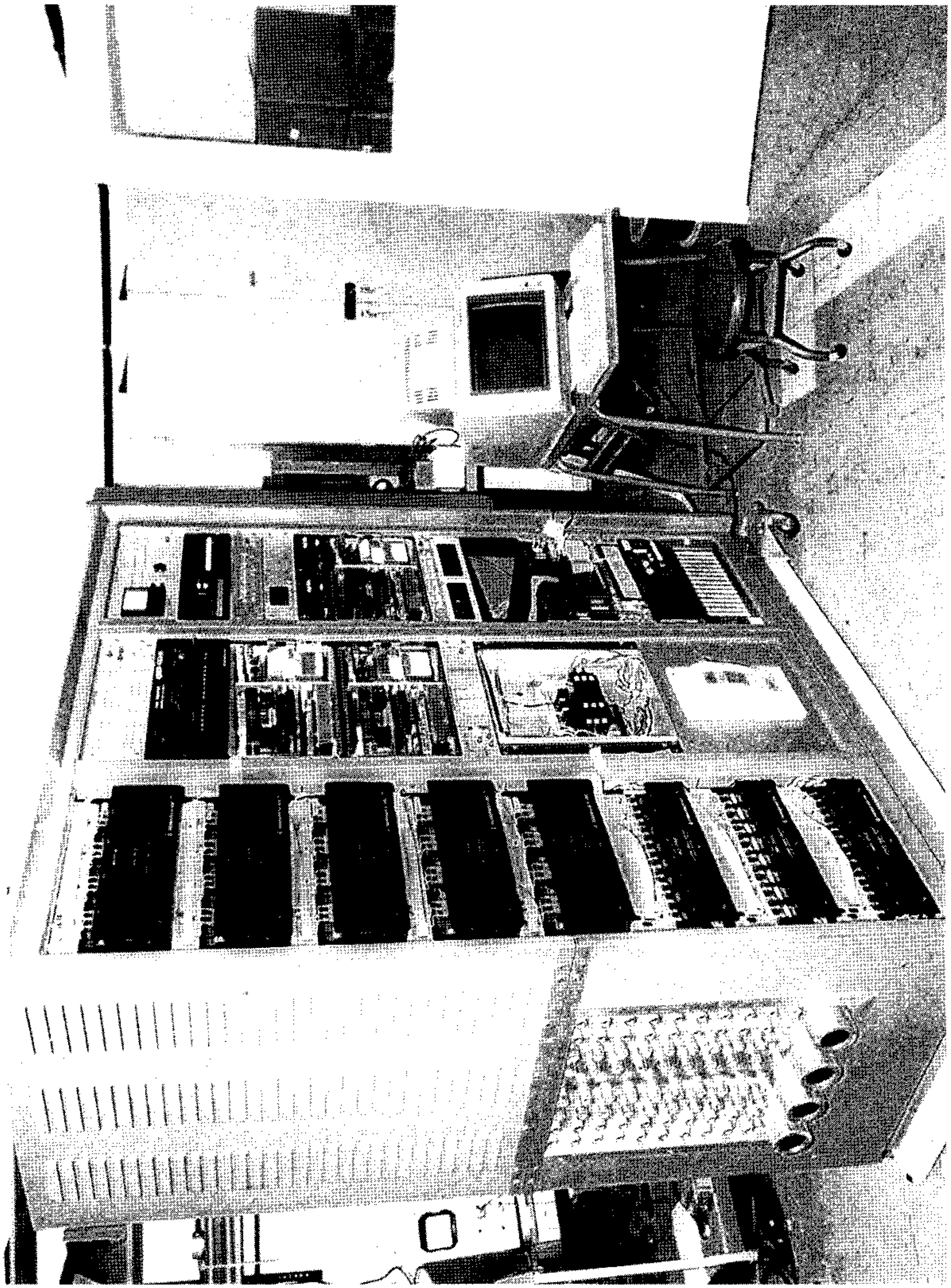


Figure 3-17. Computer Control and Data Acquisition Console.

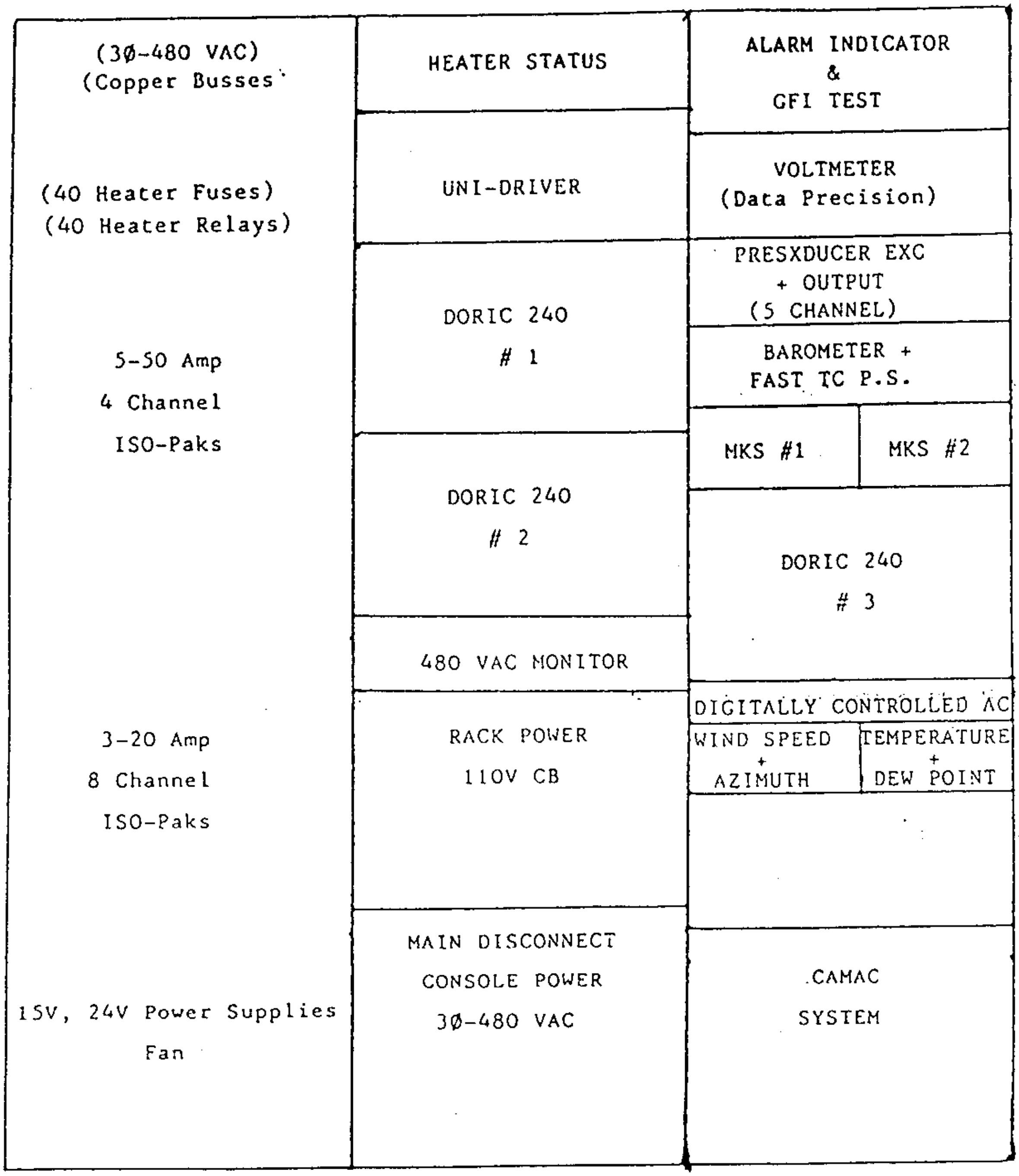


Figure 3-18. Control Console Instrumentation Layout.

Table 3-3. Control Console Instrumentation

Custom/Semicustom Subsystem

Alarm Indicator Chassis
Ground Fault Interrupt (GFI)
Heater Status and Contractor Drive
30 Main and Console Monitors (480 VAC)
5-Channel Pressure Monitor
8-Channel Digitally Controlled 110 VAC
Barometer & Fast TC Inputs
Access Panel (TC & Voltage Inputs)
Traversing Mechanism Drive Interface

Commercial Subsystems

Two MKS (Baratron) Units - Measurement & Interface System
Unidriver/CAMAC Interface
Three 100-Channel DORIC 240 Dataloggers
Wind and Azimuth System
Temperature & Dew Point Unit

Console Power System

3-Phase, 480 VAC Power Circuit (Left Bay)
- Main 3-phase Copper Buses
- Heater Fuse Blocks
- Heater Relays
- Iso-Paks/Unidriver

3-Phase 110 VAC Console Instruments/Control Power
- 15 kw, 3-Phase 480V/120V Transformer
- 3-Phase Fused Disconnect Switch
- Six 20A Load Circuit Breakers

3.3 Instrumentation

Instrumentation of the ANL Test Assembly is required to measure local surface temperatures, local and bulk air temperatures, local and bulk air velocities, and air volumetric and mass flow rates, the total normal radiative and convective components of the total heat flux, the electric power input to the heaters, and the local and total or bulk heat flux. These data will be used to evaluate the heat removal performance for particular configurations and testing conditions. The primary measurement objective is to determine the local and bulk heat flux transport rates and associated heat transfer coefficients.

Accurate measurement data are required to determine the thermodynamic state and physical properties of the naturally convected air at various elevations. The fundamental properties of the air that must be accurately measured are the temperature and pressure. The basic instrumentation for those measurements will be radiation shielded thermocouples to measure the air temperature, and pitot-static tubes in conjunction with high accuracy differential pressure transducers to measure the differential pressure.

The following sections will supply detailed information about the instrumentation, which consists of thermocouples, pitot-static traversing probes, pitot-static air flow rake, differential pressure transducers, radiation and heat flux transducers, the traversing mechanism, and the wind monitor and humidity instrumentation.

3.3.1 Thermocouples

Thermocouples for Surface Temperature Measurement

The thermocouple wire used for all the surface temperature measurements is Claud S. Gordon, type K (chromel/alumel), 24-AWG (0.020-in. dia.) twisted pair TC wire with high temperature ceramic fiber insulation on both KN and KP wires and also around the twisted pair. The insulation has a maximum temperature rating of 2600°F.[28] The limits of error for type K thermocouple wire have been establish as ± 4°F in the range of 32°F to 530°F, and ± 3/4% for the range of 530°F to 2300°F.[29] The method of installation for wall surface thermocouples, as illustrated in Fig. 3-19, is to bring the TC wire in from the opposite side of the 1-in thick steel plates through a 5/32-in. dia. hole that is countersunk 90° to a 1/4-in. hole opening. The KN and KP thermocouple wires were intrinsically spot welded about 1/16-in. to 1/4-in. apart in small grounded grooves at the edge of the countersunk hole in the steel plate; then the intrinsic TC junction and the hole were cemented over with Ceramabond-571, and smoothed flush with the surrounding surface of the plate. Ceramabond-571 is a magnesia base adhesive with a high coefficient of thermal expansion, which offers excellent adherence to metals such as steel.[30] It requires no temperature cure other than air drying prior to use at temperatures to 3200°F.

The thermocouple locations on mounting plates Nos. 1 and 2 (guard vessel wall) are shown in Figs. 3-20 and 3-21 respectively, the vertical elevations are referenced from the bottom flange of the test section weldment, and the horizontal locating reference is the north and/or south end of the plates. These vertical dimensions pertain to a heated test section of about 900°F, and accounts for the fact that the actual TC junctions are about 1/4-in. offset in the upstream direction from the TC penetration hole centerline. The accuracy of the vertical elevation is about ± 1/4-in., and the horizontal dimensional accuracy is about ± 1/16-inch. The locations of the TC hole penetrations are supplied in Mounting Plate #1 and #2 Instrumentation Penetration Spec's (ANL Dwg. Nos. R0408-0131, and -0132). In those drawings the vertical dimensions of the TC penetrations are referenced from the bottom of the plates for fabrication purposes, which is a different reference from the vertical reference in the layout in Figs. 3-20 and 3-21. In Figs. 3-20 and 3-21 all the thermocouple locations on the guard vessel wall are indicated, as well as the wire routing, the DAS identification number, and the routing identification number.

The thermocouple locations on the duct wall (back plates Nos. 1 & 2) are shown in Figs. 3-22 and 3-23, the vertical elevations are referenced from the bottom flange of the test section weldment, and the horizontal dimension is referenced from the north and/or south end of the plates. As with the mounting plates, the back plate vertical elevations pertain to a heated test section of about 900°F, and TC junctions that are offset about 1/4-in. in the upstream direction. The accuracy of the vertical elevation is similarly about ± 1/4-in., and the horizontal dimensional accuracy is about ± 1/16-in. Also,

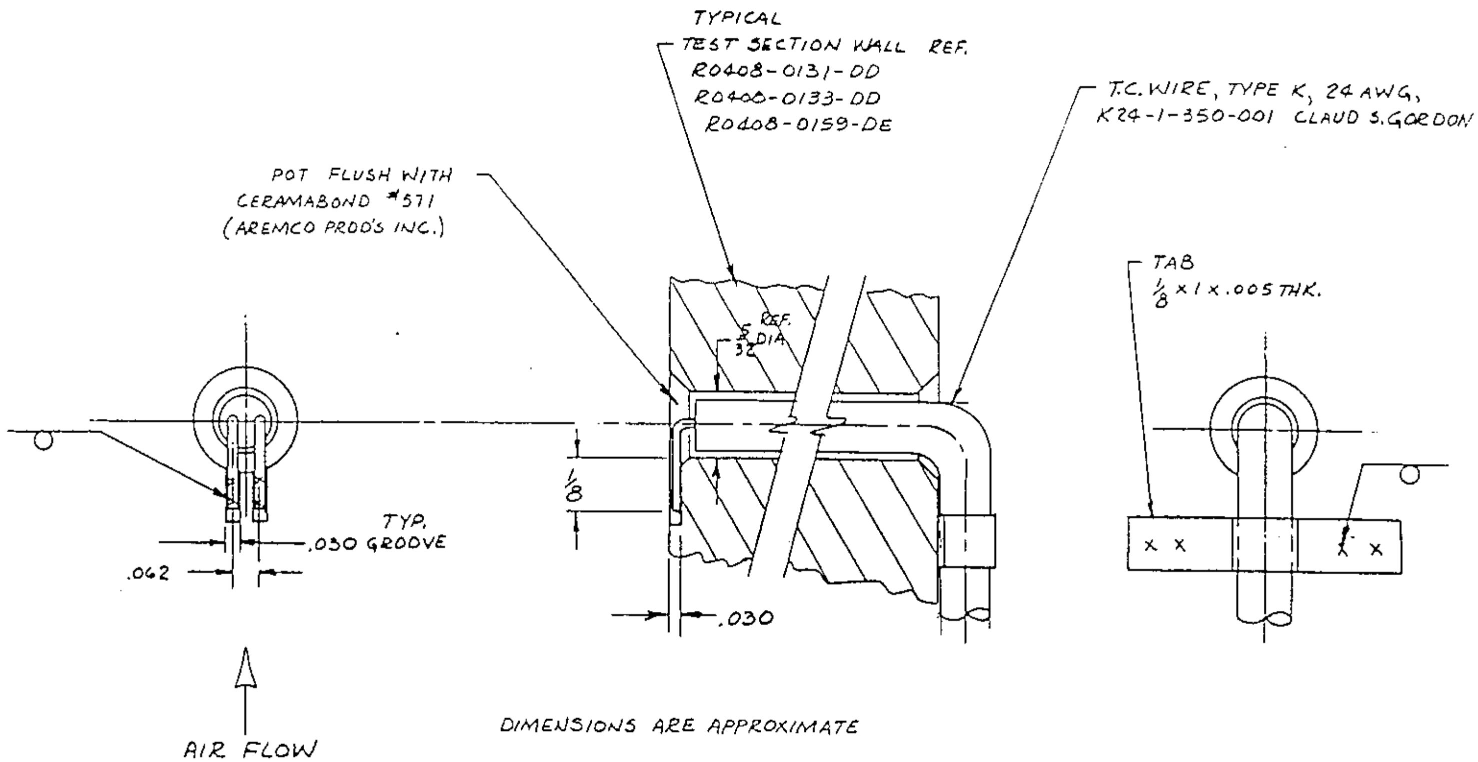


Figure 3-19. Test Section Thermocouple Installation Details (ANL Dwg. No. R0408-0617-DB).

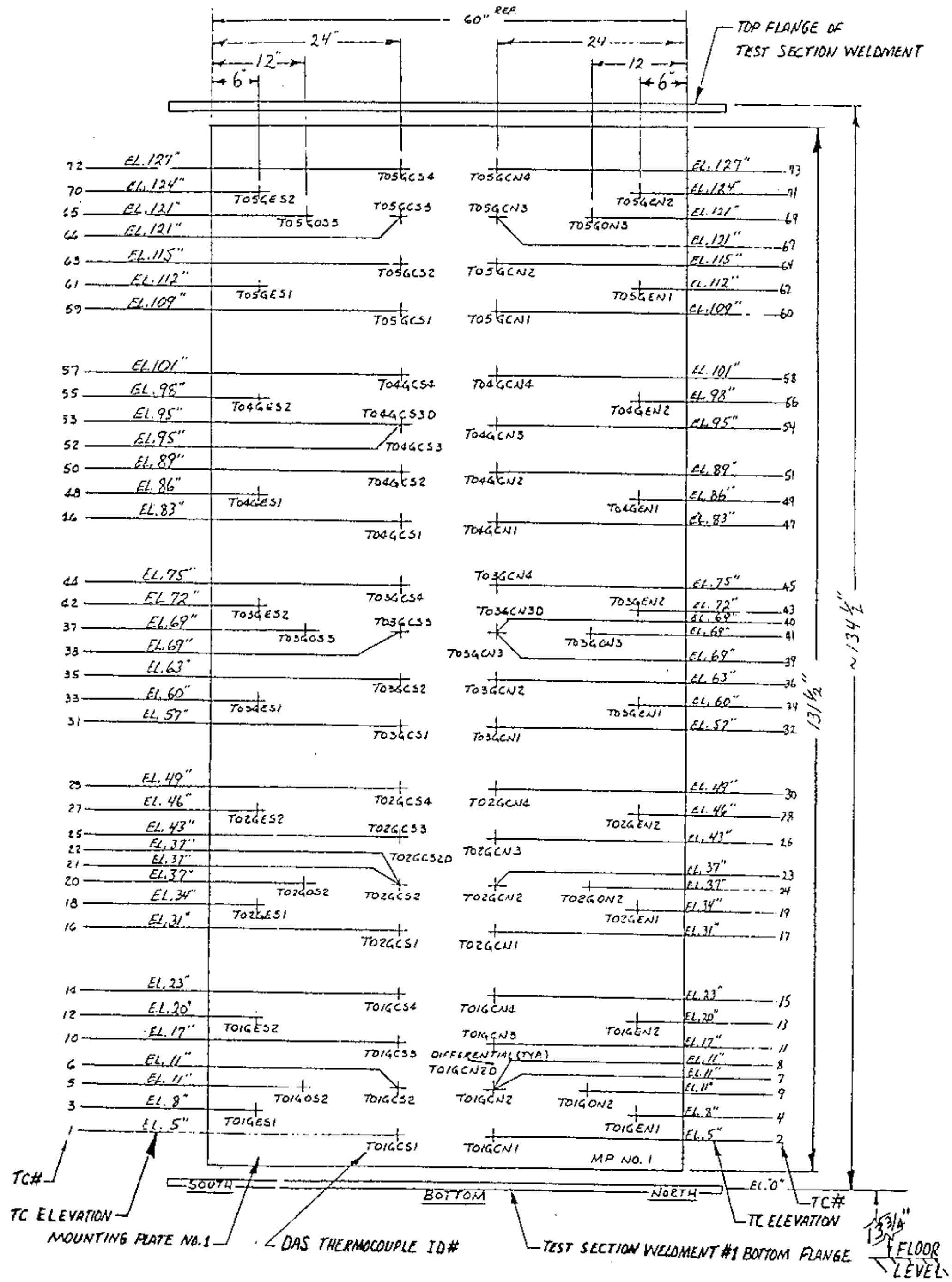


Figure 3-20. Thermocouple Locations by DAS ID# on the Guard Vessel Wall (Mounting Plate No. 1).

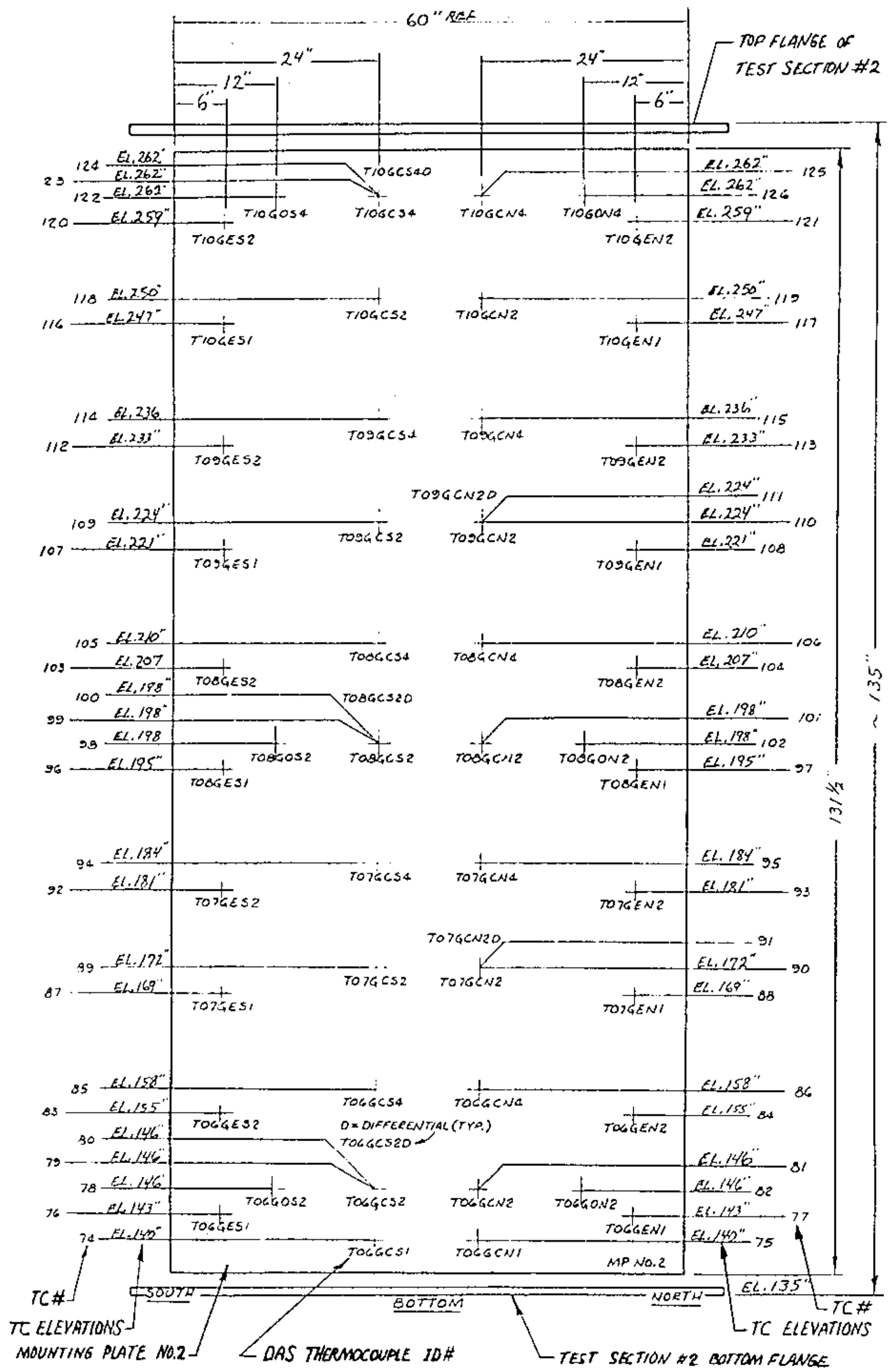


Figure 3-21. Thermocouple Locations by DAS ID# on the Guard Vessel Wall (Mounting Plate No. 2).

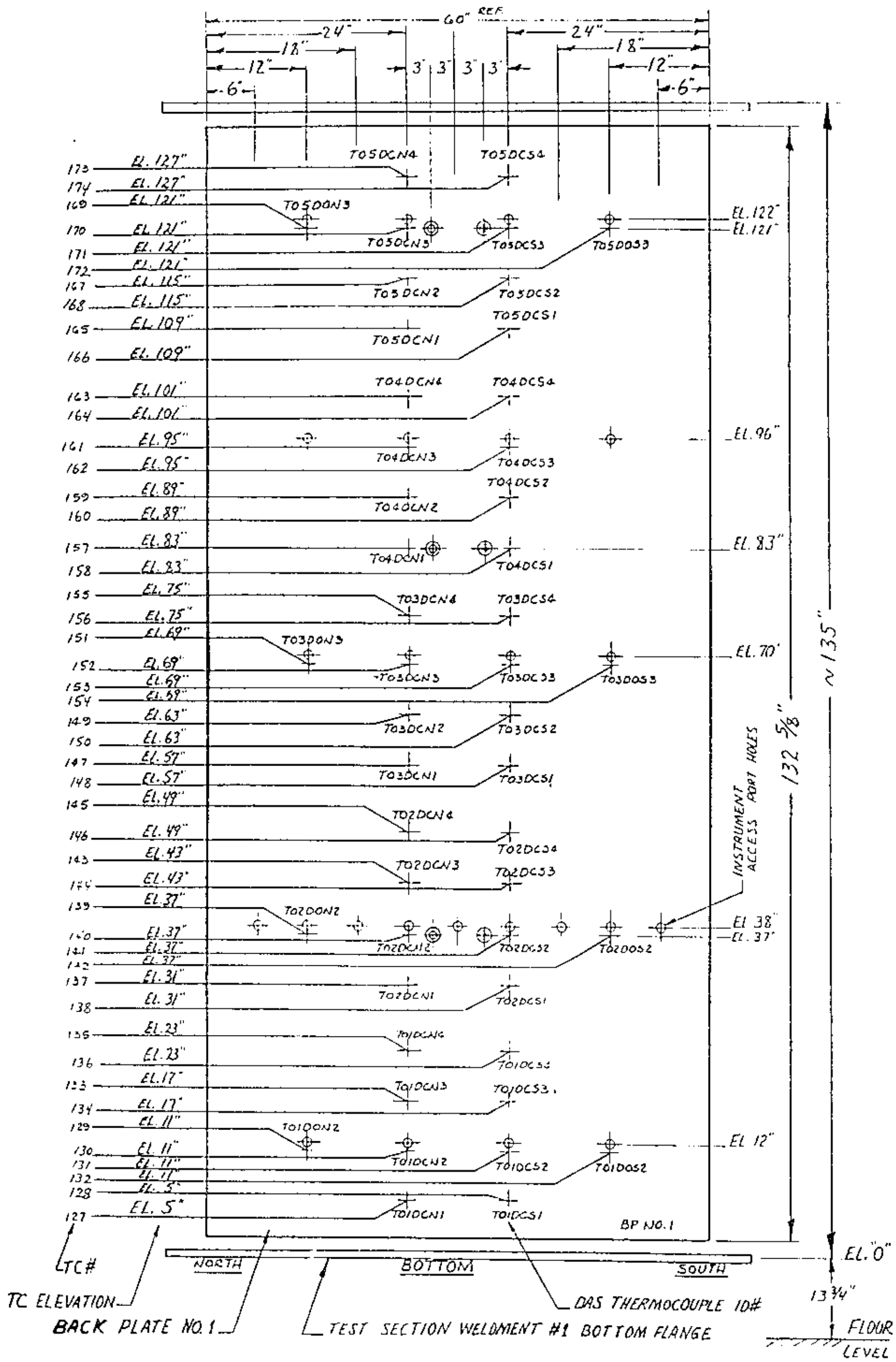


Figure 3-22. Thermocouple Locations by DAS ID# on the Duct Wall (Back Plate No. 1).

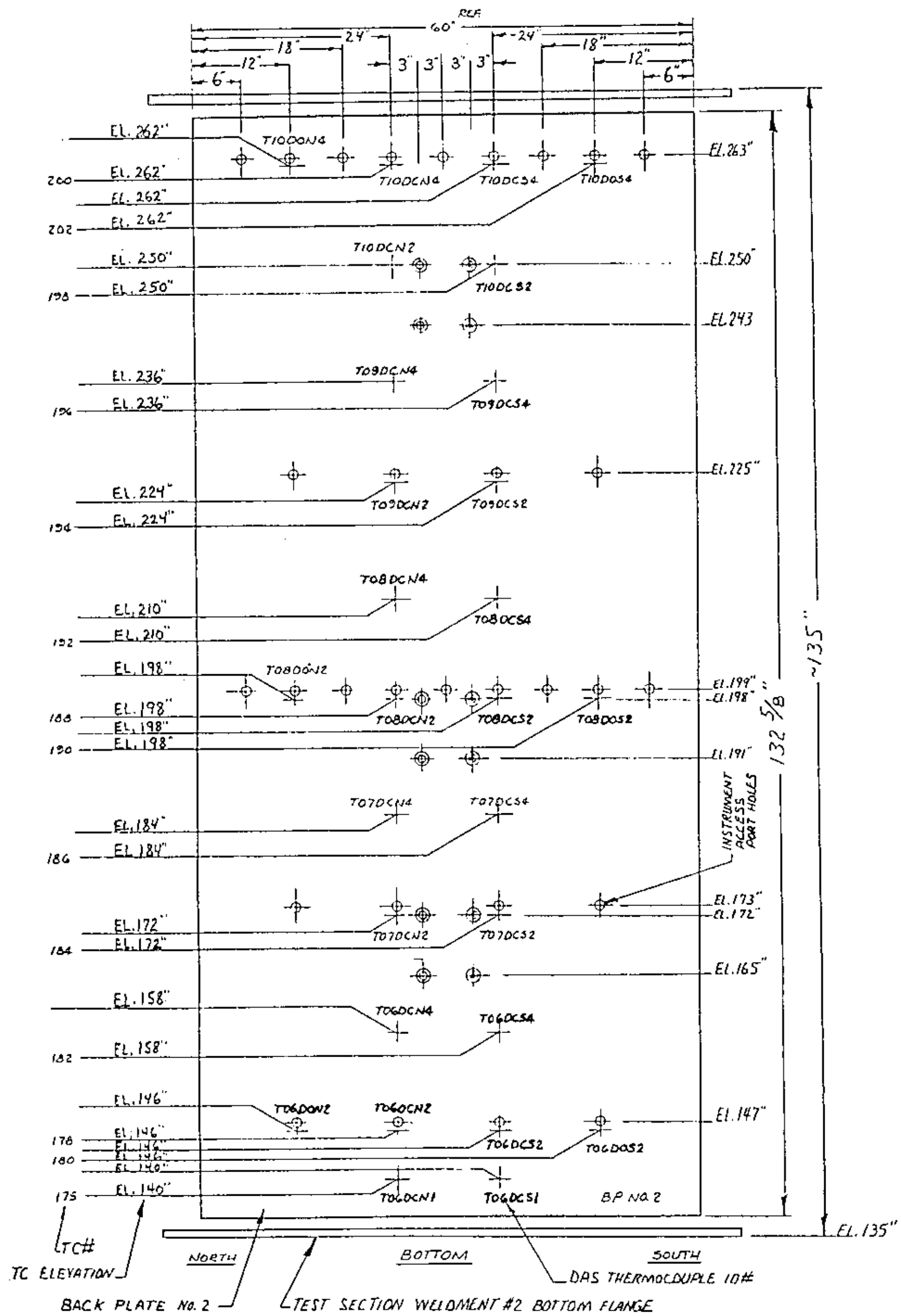


Figure 3-23. Thermocouple Locations by DAS ID# on the Duct Wall (Back Plate No. 2).

the vertical reference in Figs. 3-22 and 3-23 are different from the fabrication drawings (Back Plate #1 & #2 Instrumentation Spec's ANL Dwg. Nos. R0408-0133, and -0134). In Figs. 3-22 and 3-23 all the duct wall thermocouple locations are indicated as well as are the wire routing scheme, the routing ID number, and the corresponding DAS identification number.

The side wall thermocouple locations are indicated in the isometric sketch of the entire test section shown in Fig. 3-24. The TC measuring junction locations are located on the horizontal centerlines of the side channels at seven vertical elevations (11-in., 37-in., 69-in., 121-in., 146-in., 198-in., and 262-in.) on both the north and south sides.

The heater overtemperature thermocouple locations are indicated in the heater wiring diagrams shown in Fig. 3-25, for test section #1, and in Fig. 3-26, for test section #2. The routing scheme and routing ID numbers, and the DAS numbers are shown in those drawings. Figure 3-27 shows how these TC's were attached to the washer on the heater plate stud bolt.

Radiation Shielded Thermocouples For Air Temperature Measurement

Figure 3-28 shows a sketch of the radiation shielded TC probe, and its positional relationship with the pitot-static probe. Figure 3-29 shows a 4X-scaled drawing of the modified United Sensor shielded TC head. For air temperature measurement the time constant (the time required to reach 63% of an instantaneous temperature change) is a primary consideration. Calculations were performed to ascertain the effect for 28-AWG, C/A thermocouples for the temperature range of from 100°F to 400°F, and for flow velocities of 2-ft/s to 30-ft/s.[31] Those calculations showed that the thermocouple's convective heat transfer coefficient, and its time constant are strongly a function of the flow velocity over the TC bead, and the bead diameter, and only very weakly a function of temperature. In general, a factor of 2 increase in the flow velocity will reduce the time constant by a factor of 2, and a reduction in the bead diameter by a factor of 2 will reduce the time constant by a factor of 3. The actual time required for these thermocouples to respond to a change in air temperature of 20°F (from 100°F to 120°F) and reach to within 0.1°F of the 20°F change (i.e. 119.9°F) are as follows:

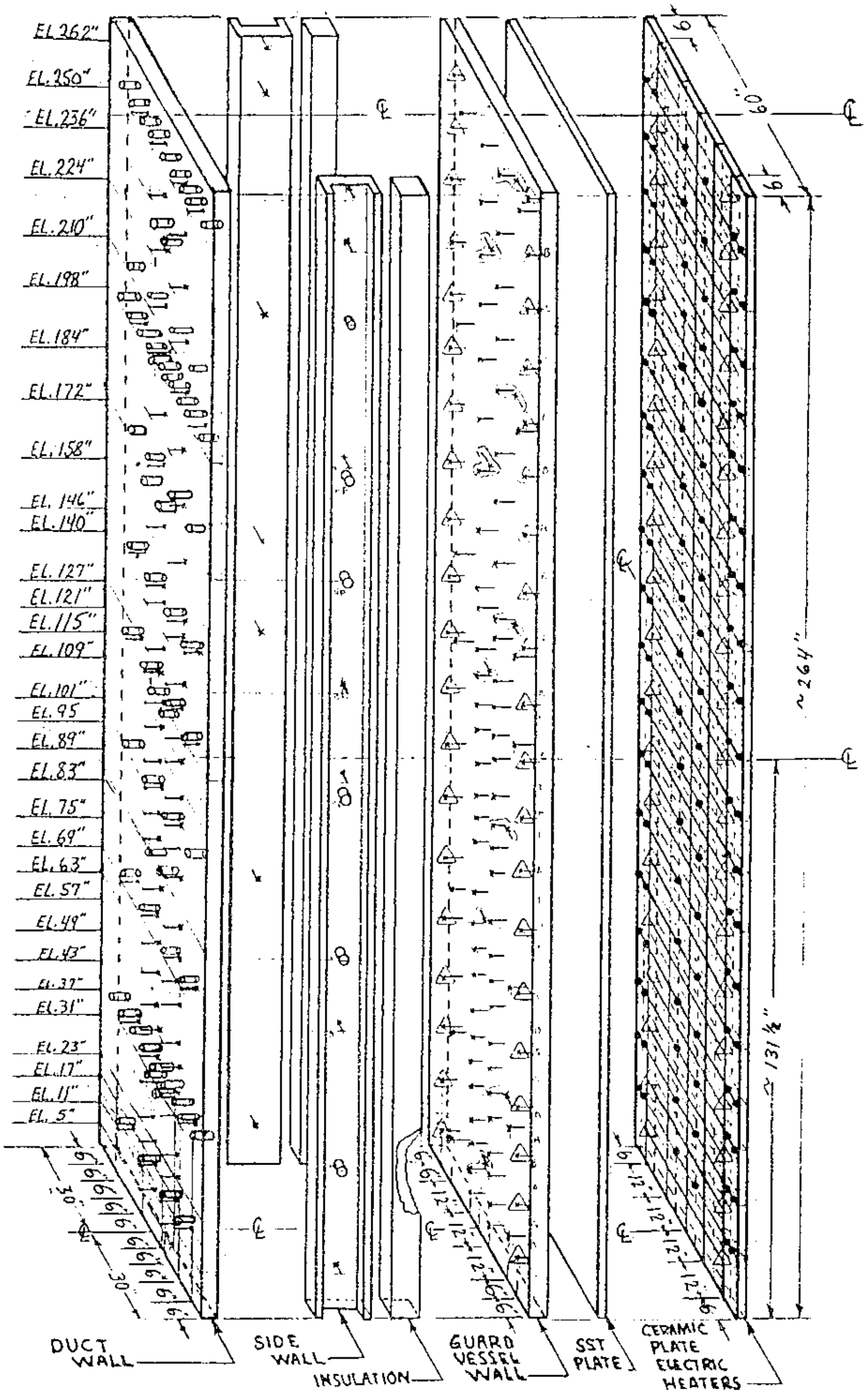


Figure 3-24. Isometric Illustration of Test Section Showing Thermocouple and Access Port Locations.

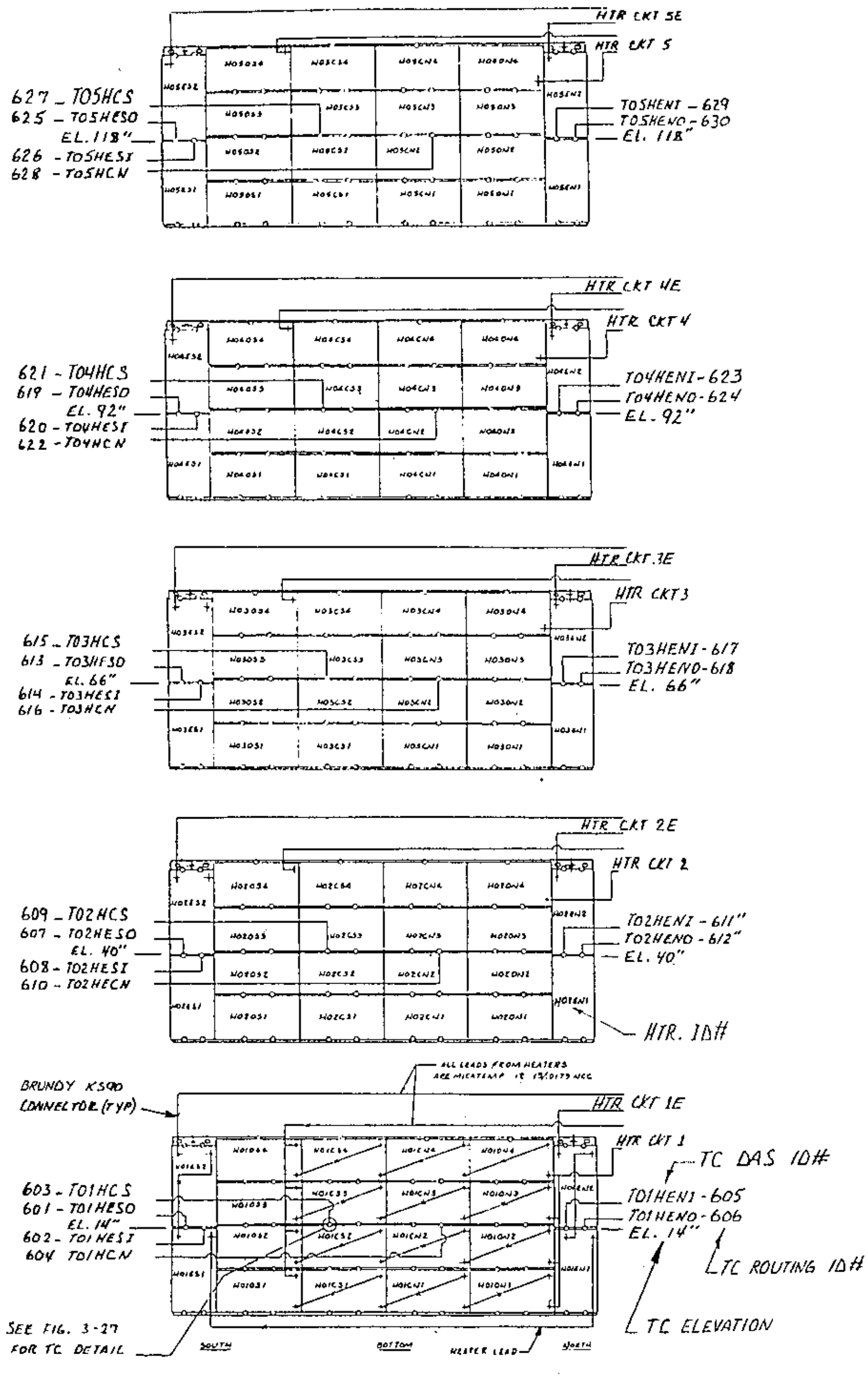


Figure 3-25. Heater Wiring Diagram Showing Overtemperature Thermocouple Locations on Test Section #1.

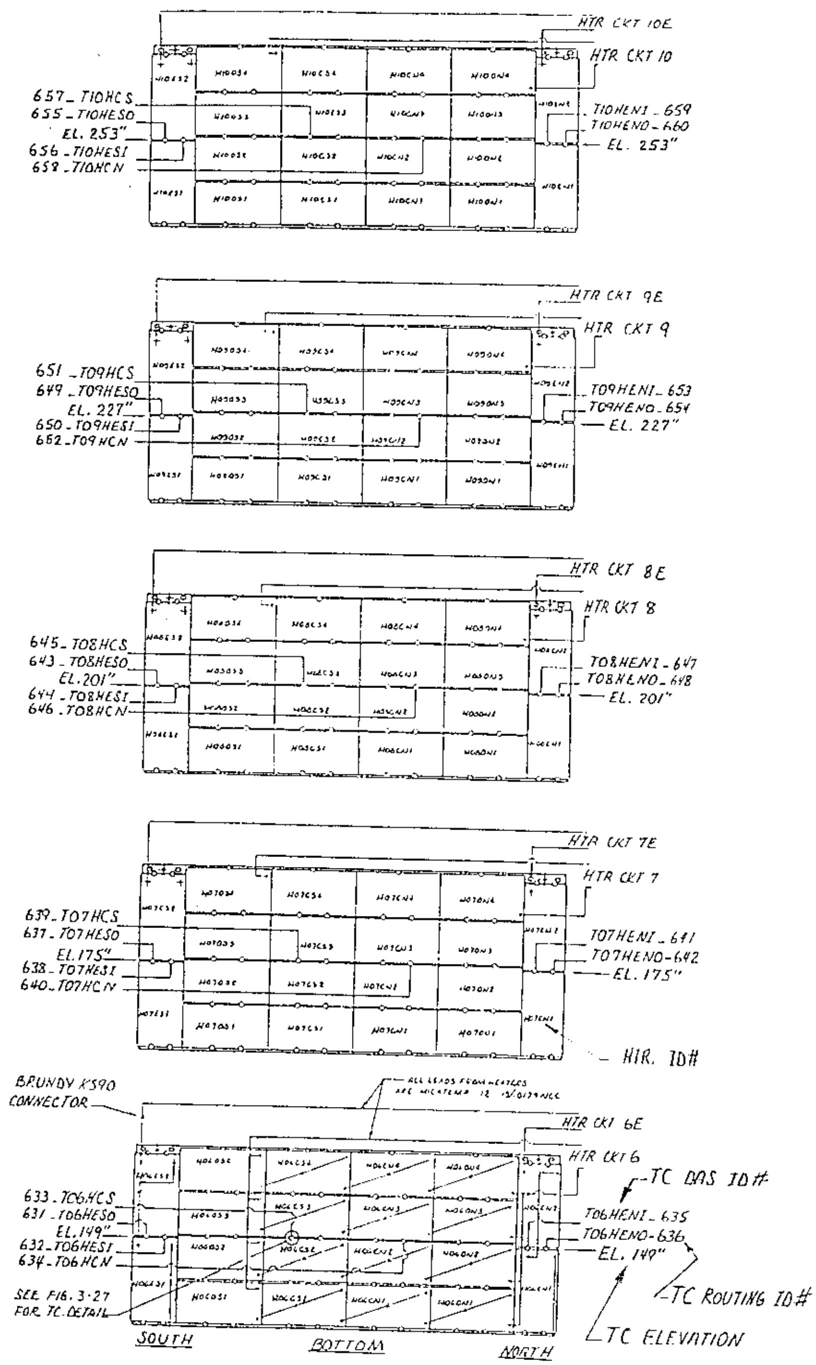


Figure 3-26. Heater Wiring Diagram Showing Overtemperature Thermocouple Locations on Test Section #2.

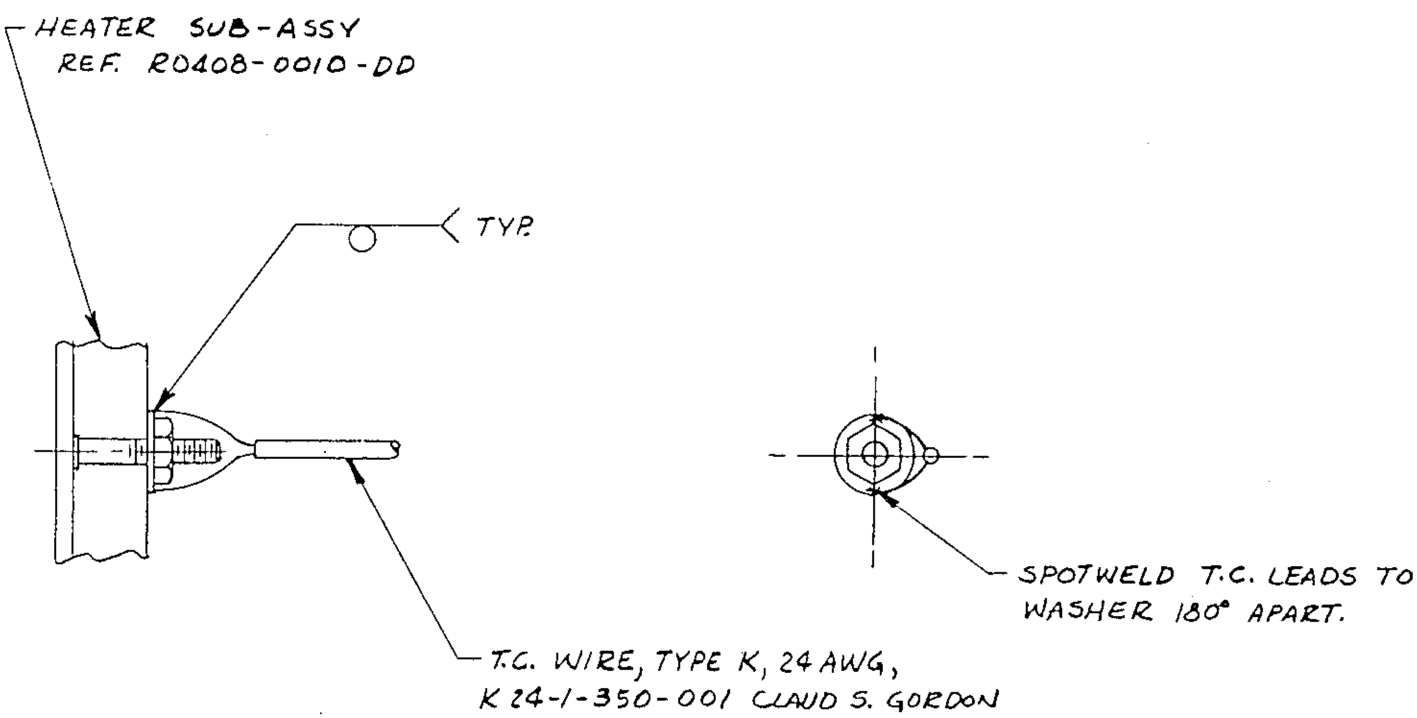


Figure 3-27. Heater Overtemperature Thermocouple Installation Detail.

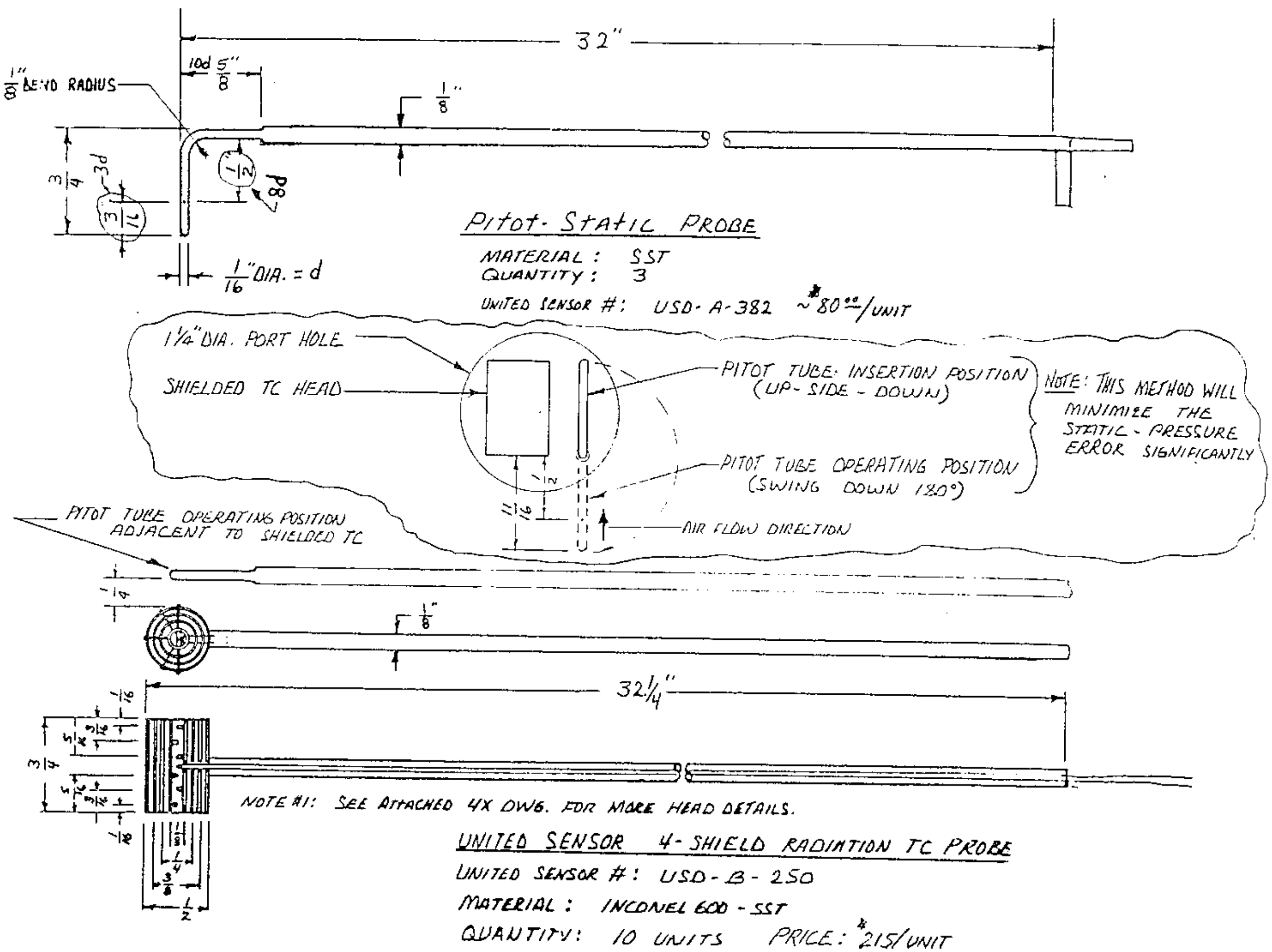


Figure 3-28. Design of the Pitot-Static Probe and Radiation Shielded Thermocouple Probe.

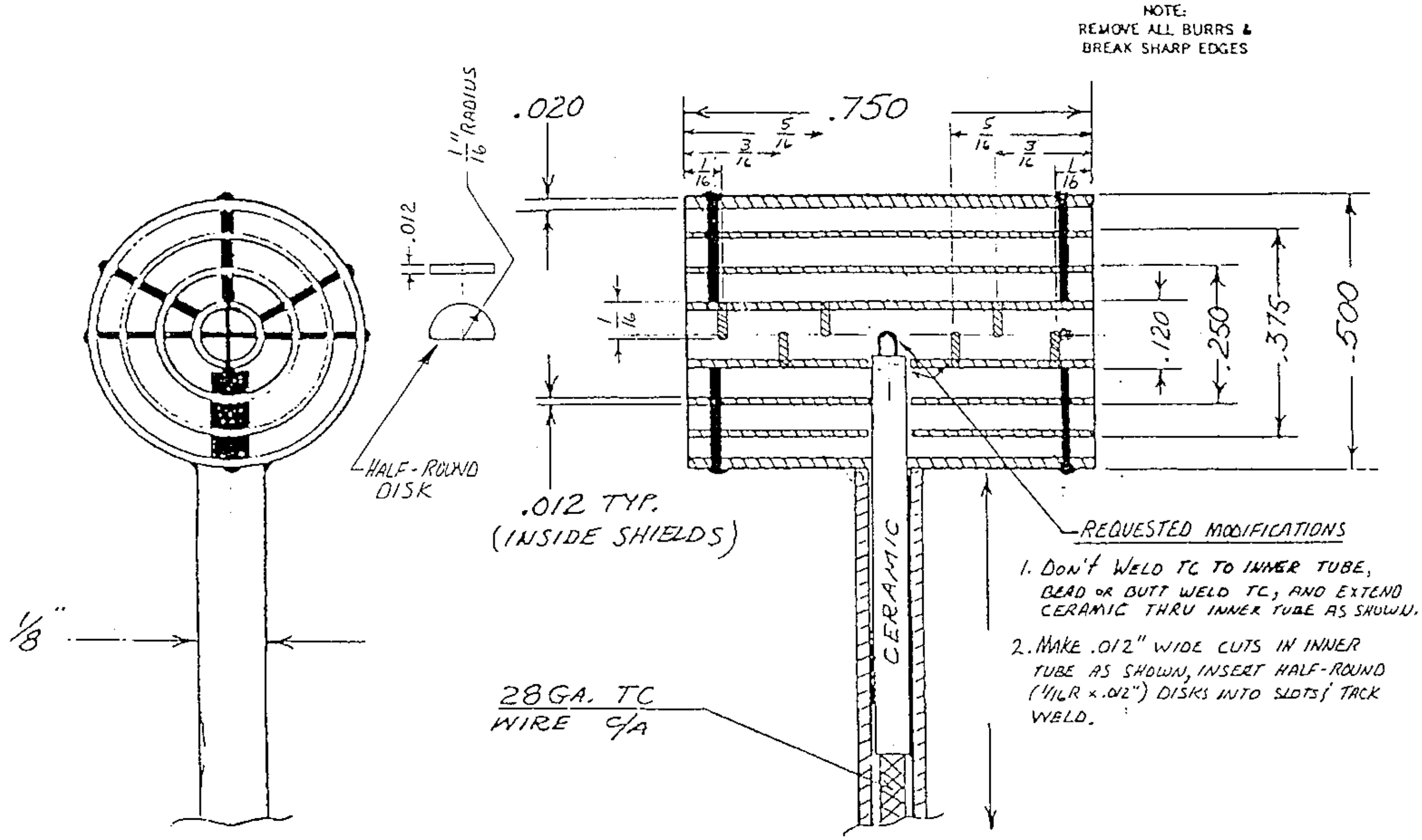


Figure 3-29. Enlarged 4X-View of the 4-Shield Radiation TC Head.

a. 136-s at 2-ft/s air velocity,
b. 52-s at 15-ft/s air velocity,
c. 36-s at 30-ft/s air velocity.

Ten of the United Sensor radiation shielded thermocouples were purchased for use, four are for measuring the inlet air temperature at ~3 ft. upstream from the heated test section, four are for measuring the outlet air temperature at the VOLU air flow rake (~12 ft. downstream from the heated test section), and one (plus a spare) will be used for local traversing differential pressure measurement. Both the inlet and outlet thermocouple probes will be movable in and out of their access ports for changing positions within the duct, however, the initial positions of the inlet and outlet shielded TC's are indicated in Figs. 3-30 and 3-31 respectively.[32]

Unshielded Thermocouples For Air Temperature Measurement

At the chimney exit there are 12 beaded, unshielded, standard type-K thermocouples that are arranged in sets of four (north, south, east, and west chimney midplanes), at three elevations (chimney top, 2-ft., and 4-ft. below), and each TC being about 3-in. from the chimney wall.[33]

3.3.2 Pitot-Static Traversing Probes

The design of the pitot-static traversing probe is shown in Fig. 3-28, and its orientation with respect to the radiation shielded TC probe is also shown in that figure. Note in Figs. 3-28 and 3-32 that the pitot-static tube is inserted through the port hole side-by-side with the shielded TC probe with its tip pointing downstream in the direction of air flow, then for measurement operations the tip is turned 180-degrees so that it then points upstream, and is parallel with the air flow. This positioning operation locates the total pressure hole in the tip at 11/16-in. upstream, and the static pressure hole at 1/2-in. upstream, and 1/4-in. offset from any perturbance from the shielded TC head.[34] This orientation was used because side-by-side temperature and velocity measurements were required, but the closeness of the sensors would likely introduce an unknown systematic error that would be difficult to calculate with any precision because of probable turbulence. However, as Figs.

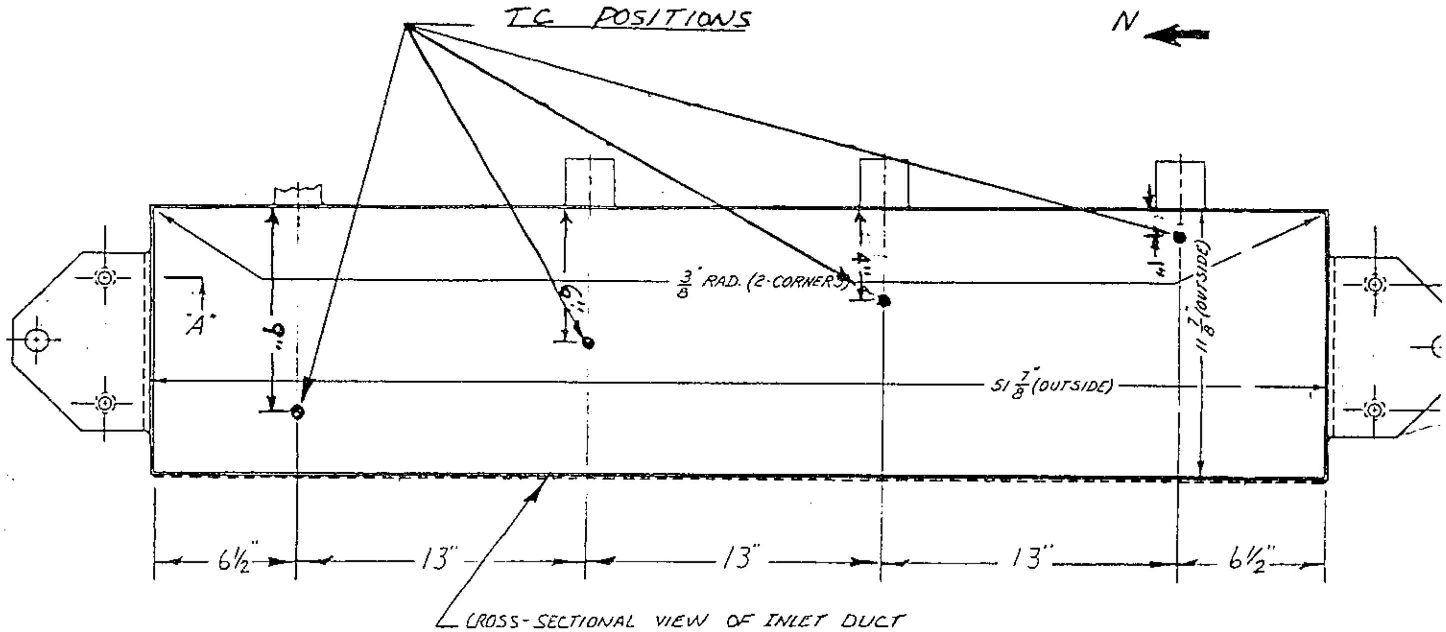


Figure 3-30. Inlet Positions of the Radiation Shielded Thermocouples.

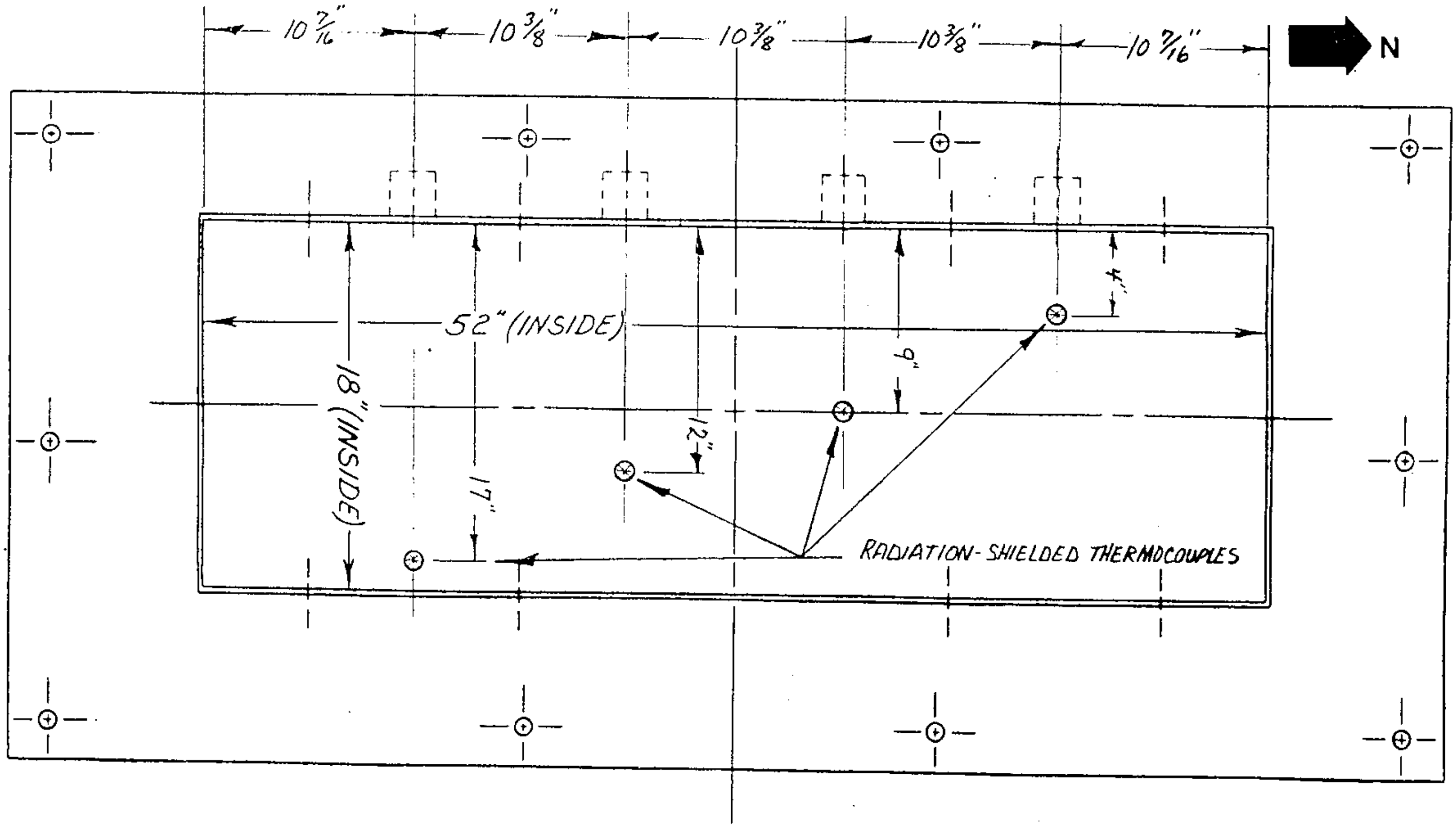


Figure 3-31. Outlet Positions of the Radiation Shielded Thermocouples.

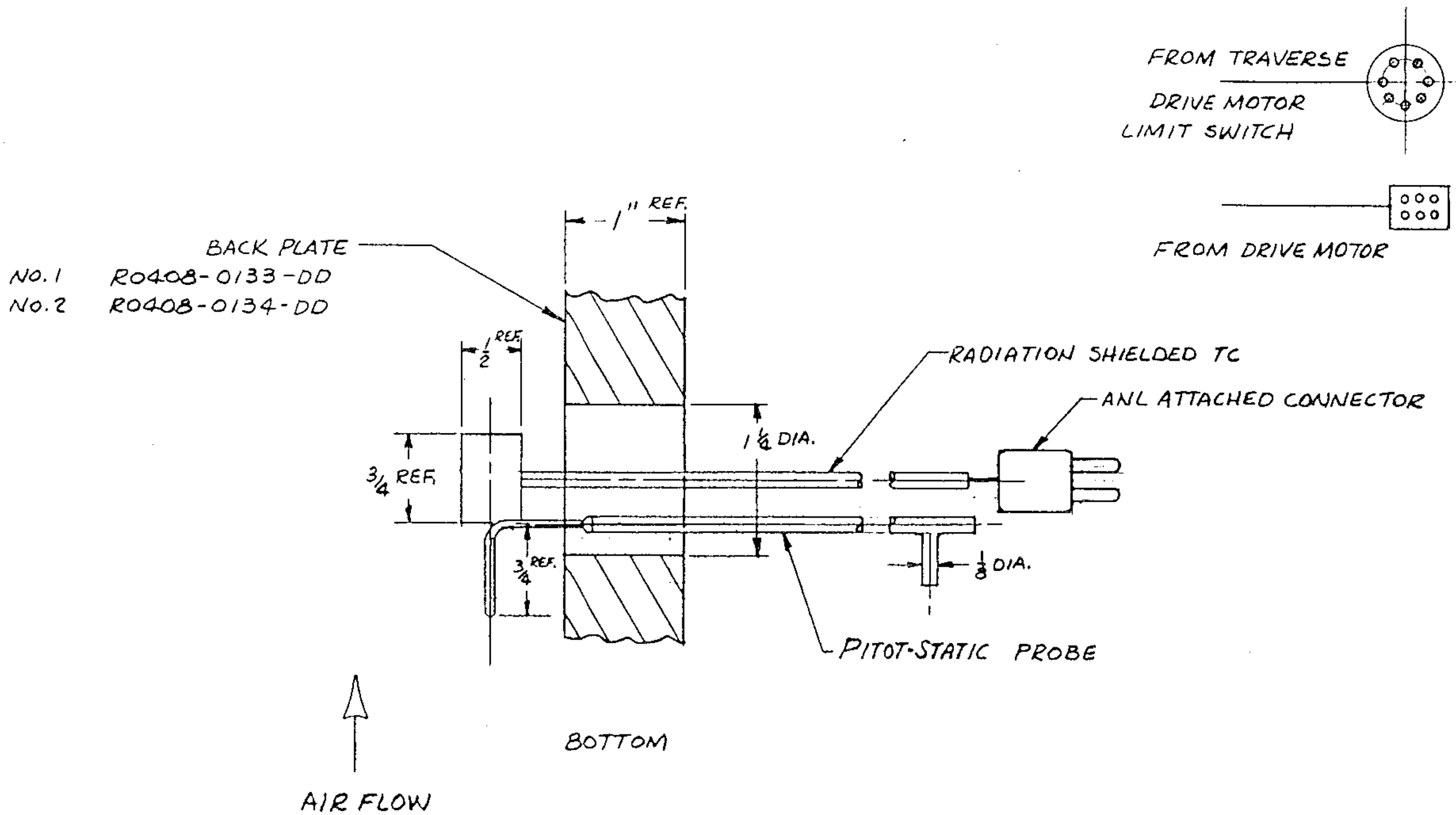


Figure 3-32. Pitot-Static and Radiation Shielded Thermocouple Probes in Operating Position.

3-33, and 3-34 show, the measurement error is significantly reduced for greater distances away from the source of the perturbance.[35] Figure 3-34 can be use to estimate the systematic error for the pitot-static probe that will be used for RVACS tests, which is shown in Fig. 3-28. For the dimension d1 = 3D, a systematic error of about -0.90% is predicted, and for the dimension d2 = 8D, a systematic error of about 1.0% is predicted; therefore, since these effects are additive and tend to cancel, the overall systematic error should be (1.0% - 0.90%) = 0.1% for the pitot-static probe shown in Fig. 3-28.[36]

3.3.3 Pitot-Static Air Flow Rake

The pitot-static air flow rake is an Air Monitor Corporation VOLU-probe, which consists of a group of five multiple-sensing pitot-static probes that span the outlet duct, and average the sensed values (total and static pressure) in separate manifolds.[37] There are five total and five static pressure taps in each of the five probes for a total of 25 total and 25 static pressure measurement points within the cross-sectional area (12-in. x 52-in.) of the duct. The rake is located on a horizontal plane near the bottom end of the Vertical Short Duct Section (ANL Dwg. No. R0408-0108-DD) at approximately 12-ft. above the top of the 22-ft. test section; one probe is 5-1/4 in. from the inside south end, another probe is located 5-1/4 in. from the inside north end, and the remaining three probes are spaced 10-3/8 in. apart between the two outside probes.

The primary considerations for the selection of the pitot-static rake to measure the outlet air velocity and volume flow rate in the RVACS test assembly are as follows:

1. The location of the measurement is at a somewhat inaccessible elevation of about 35-ft. above floor level where quasi-permanent installation is required.

2. Since the velocity profile will at times be parabolic in both x- and y-directions, multiple point measurements on a horizontal plane must be averaged together to obtain a more accurate bulk flow measurement.

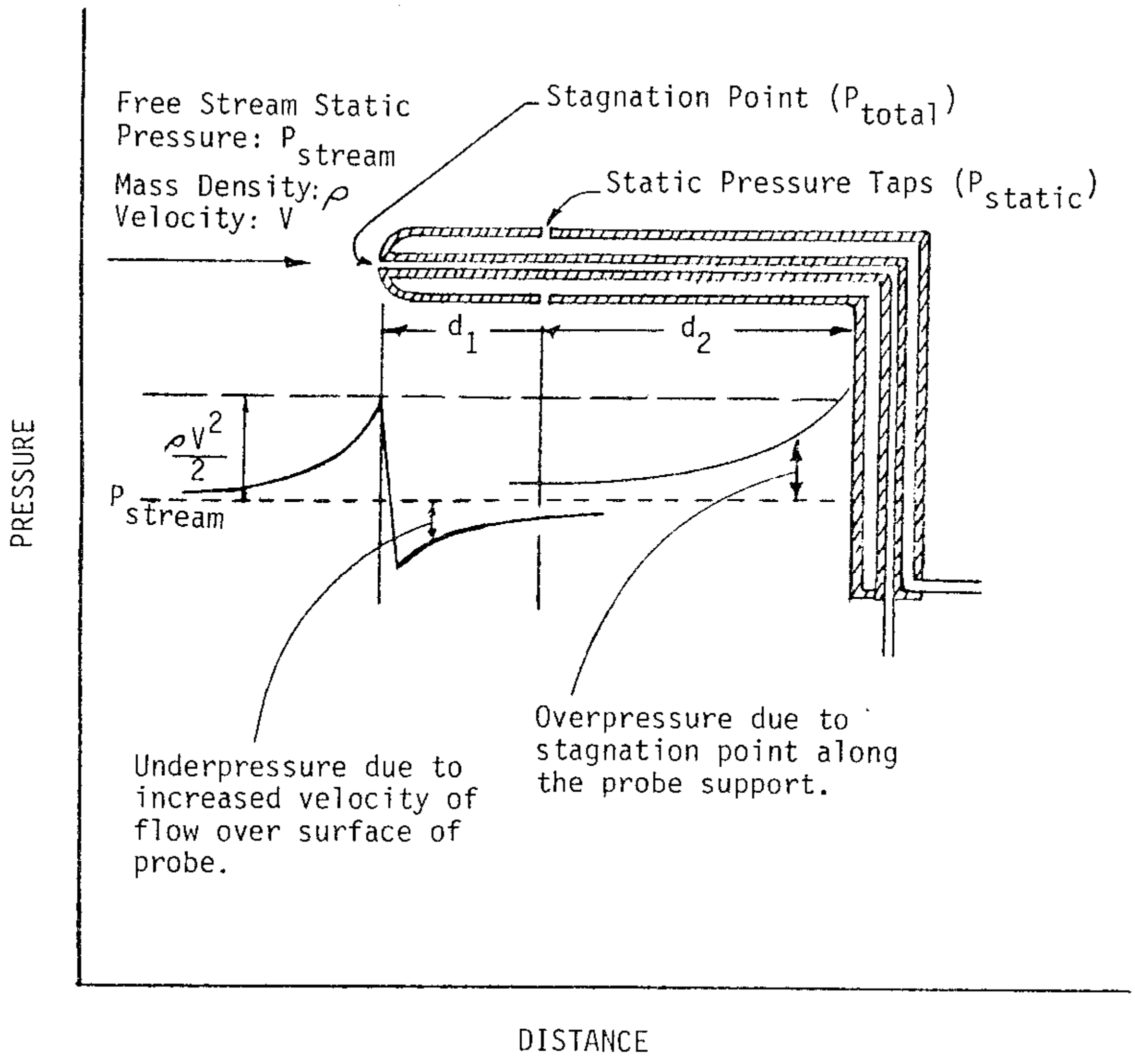
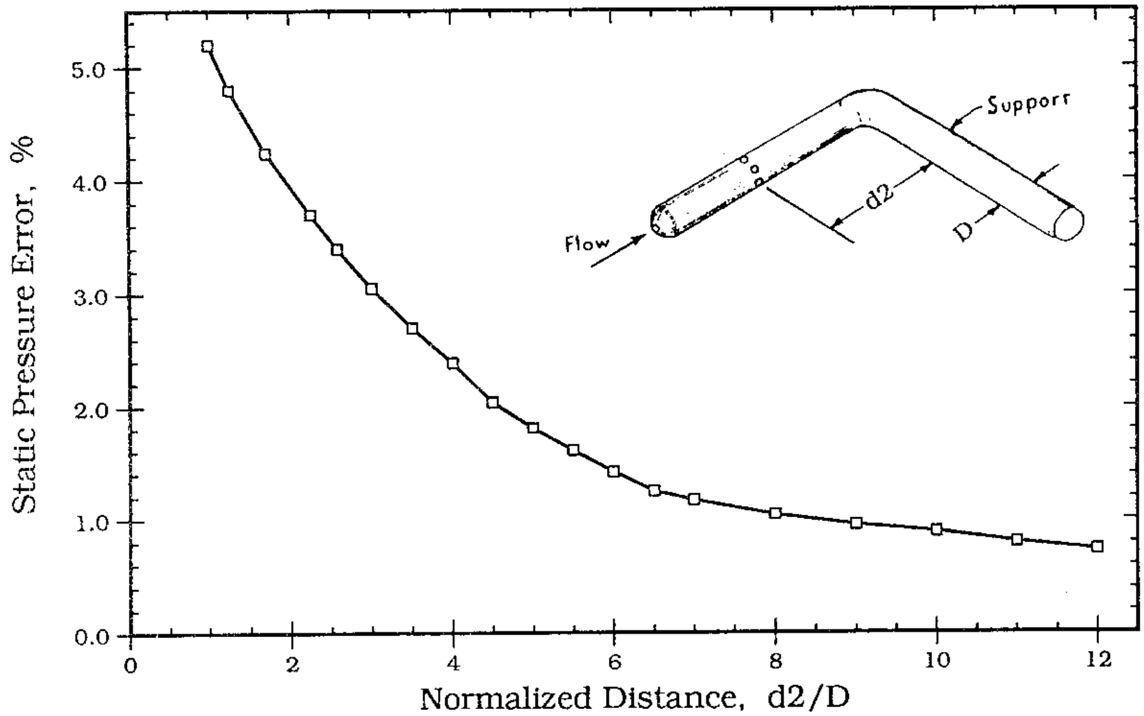


Figure 3-33. Pitot-Static Probe Geometry Effects on Pressure Over Surface of Probe (Adapted from Ref. 35).



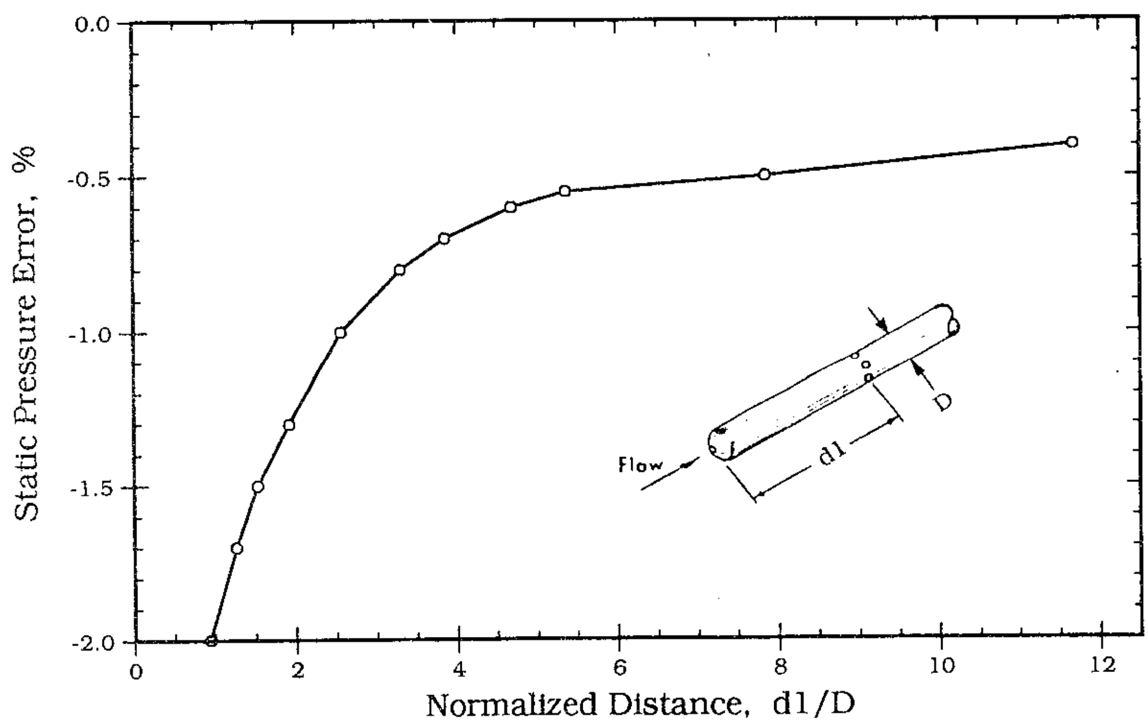


Figure 3-34. Static Pressure Error for Pitot Tubes
(Adapted from Ref. 35 and 36).

3. The temperature of the air is not expected to be greater than 300°F, therefore the lower priced aluminum probes were purchased.

4. The optimum accuracy based on technical reasoning and cost was targeted at 2% (meaning that it is desired to measure the air flow to within 98% of the actual flow rate).

3.3.4 Differential Pressure Transducers

The differential pressure measurement instruments should provide accurate differential pressure measurements in the flow range of 2 ft/s at 80°F to 30 ft/s at 150°F.[32]

The pressure transducer system required to measure the differential pressure in the range required consists of three major components, sensor, signal conditioner, and power supply. The MKS Baratron Model 398H differential pressure transducer system satisfied all the requirements and therefore two such instruments were purchased for the RVACS tests. The characteristics of the 398H MKS Baratron are listed in Table 3-4; additional information about the pressure transducer, signal conditioner, power supply, and electronic accessories can be obtained from the manufacturer.[38]

3.3.5 Radiation and Heat Flux Transducers

The design requirements for the in-wall mounted radiometers and heat flux transducers, and the radiometry/emissivity measurement apparatus were as follows:[39]

Requirements for the In-Wall Radiometer and Heat Flux Transducer

1. Locations for these transducers have been designated at six elevations in the duct wall of the 22-ft. test section, however, only two each of these particular transducers were purchased, therefore, the capability of repositioning the detectors during a test is required.

2. The face of the detectors should be flush with interior duct wall surface when fully inserted into operating position.

3. The length of the SST water cooling tubes on the radiometer need to be increased to extend out through the insulation (20-in. lengths were ordered but they were delivered with 3-in. long cooling tubes).

4. Water supply and exhaust lines need to be incorporated into the design.

Requirements for the Emissivity Measurement Apparatus

1. Insulated containment tubes are required for the detectors and their lead and TC wires, and water cooling tubes.

2. The face of the radiometer should be positioned about 1-in. from the wall surface for either the guard vessel or duct wall emissivity measurements, and radiation-shadowing or -reflecting from other body surfaces should be extremely minimized or eliminated (i.e. the face of the sensor should see only the direct, unattenuated radiation from the particular wall surface being measured).

3. For guard vessel wall emissivity measurements the radiometer assembly should be capable of being moved to any other desired port hole in the duct wall; for the duct wall measurements the radiometer assembly should be capable of being moved to other side-wall port holes and capable of retractable sliding movement along the horizontal plane from the horizontal centerline of the G. V. wall and duct wall to about 6-in. from the entrance side wall.

Table 3-5 presents a list of specifications and useful information pertinent to the Schmidt-Boelter radiometer transducer, and Table 3-6 lists specifications for the gold-plated heat flux transducer. Certificates of calibration, and calibration curves for each transducer are supplied in Appendix A.[40]

Table 3-4. MKS Baratron Differential Pressure Transducer Characteristics

Make & Model:	MKS Baratron 398H
Cost:	$3090 each, complete unit
Unit Includes:	1. PT Sensor 2. Signal Conditioner 3. Power Supply 4. Additional Electronics 5. Temperature Control Unit
Pressure Range:	x1, x0.1, x0.01 mm Hg (full scale)
Resolution:	1×10^{-6} F.S. (1.0×10^{-6} to 1.0×10^{-8} mm Hg)
Accuracy:	STD: ± 0.08% R (all ranges)
Temperature Zero: Span:	< 0.0004% F.S./°C < 0.002% R/°C
Operating Temperature:	Controlled at 45°C
Time Constant:	< 25 ms
Input:	100-135 VAC or 200-270 VAC (50-60 Hz)
Output:	0 to ± 10 VDC

Table 3-5. Specifications and Descriptions of the Schmidt-Boelter Radiometer

1. SENSOR TYPE and MODEL No.: Schmidt-Boelter Radiometer, Midtherm Corp., Model No. 64-1.0-10MgO-36-20K/KRS5W-IC-150 (1-in. basic diameter) Model No. 24-1.0-36MgO-36-18K/KRS5W (3/8-in. basic diameter).

2. CONSTRUCTION MATERIAL: The body of the transducer is gold-plated over pure copper, and the flanges and water-cooling tubing are 304 stainless steel.

3. PRINCIPLE OF OPERATION: The incident heat flux is absorbed at the sensor surface, and is transferred in a direction normal to the absorbing surface to an integral heat sink, which remains at a temperature below that of the sensor surface. The difference in temperature between two points along the path of heat flow from the sensor to the sink is proportional to the heat being absorbed. Thus, a differential thermo-electric circuit provides a self-generating emf between the two output leads, which is directly proportional to the heat transfer rate.

4. RANGE: 0.0 to 1.0 Btu/ft^2-sec.

5. OVERRANGE CAPABILITY: 500%.

6. OUTPUT SIGNAL: 10 ± 1.5 millivolts at full range.

7. MAXIMUM ALLOWABLE OPERATING BODY TEMPERATURE: 400°F.

8. ACCURACY: ± 3% FR.

9. MAXIMUM NON-LINEARITY: ± 2% FR.

10. REPEATABILITY: ± 1/2%.

11. CALIBRATION: Certified calibration provided with each transducer.

12. WINDOW MATERIAL: Thalium Bromo-Iodine (KRS-5).

13. REMOVABLE WINDOW: The KRS-5 window is removable. When the window is attached the convective heat transfer is eliminated, thus making the transducer a total radiation heat flux transducer. When the window is removed the air is allowed to flow over the sensor surface, and a lower heat flux is measured, which is the total radiation heat flux minus the convective heat flux. Both the total normal incident radiation, and the convective heat flux are parameters to be measured.

14. SPECTRUM TRANSMITTED BY THE KRS-5 WINDOW: The transmittance is 99.9% from 0.5 μm flat to 60 μm, i.e., at 650°F the radiation spectrum is 82% below 12 μm, 98% below 30 μm, and 99.9% below 60 μm.

Table 3-5. Specifications and Descriptions of the Schmidt-Boelter Radiometer (cont'd)

15. RESPONSE TIME (63.2%): < 1.5 sec.

16. NOMINAL IMPEDANCE: < 100 ohms.

17. HEAT ABSORPTION: The amount of heat that can be absorbed by the transducer in an adiabatic (perfectly insulated thermally) installation before exceeding the 400°F limitation is 4.2 Btu for the water cooled model but without water in its passage.

18. WATER COOLING: The recommended water flow rate is 0.25 GPM at 40 psi which should be sufficient to keep the detector body temperature optimally below 400°F.

Table 3-6. Specifications for the Midtherm Gold-Plated Sensor Transducer

1. SENSOR TYPE and MODEL No.: Conduction/convection heat flux transducer with the sensor face gold-plated. Medtherm Corp. Model No. 40-0.875-1.0-10MgO-36-20681KGP.
2. CONSTRUCTION MATERIAL: Body of pure copper with gold-plated sensor.
3. PRINCIPLE OF OPERATION: The transducer provides a linear output that is directly proportional to the net absorbed conducted/convected heat flux transfer through the sensor.
4. RANGE: -1.0 to 1.0 Btu/ft^2-sec.
5. OVER-RANGE CAPABILITY: 500%.
6. OUTPUT SIGNAL: 10 ± 1.5 millivolts FR.
7. MAXIMUM NON-LINEARITY: ± 2% FR.
8. ACCURACY: ± 3% FR.
9. REPEATABILITY: ± 1/2%.
10. MAXIMUM OPERATING BODY TEMPERATURE: 650°F.
11. CALIBRATION: Certified calibration provided.

3.3.6 Traverse Mechanism

The traverse mechanism consists of a Velmex Co., UniSlide, Series RVB4000 power traverse unit that has been adapted for making computerized, programmed traverses with the radiation-shielded TC probe and pitot-static probe combination.[41] Figure 3-35, which is a reduction of ANL Dwg. No. R0408-0031-DD, shows the traverse mechanism in operating position with the probes attached.

The basic requirements for the design of the traverse mechanism were as follows:[42]

1. A reference measurement is required to verify the distance from the guard vessel wall to the duct wall.

2. A consistent reference point is required for all measurements; the air-side surface of the duct wall (back plate) will be the fiducial reference point for all measurements.

3. For all routine measurements the following requirements shall apply:

   a. Positioning: It shall be possible to position measurement sensors to within ~ 3/8-in. from a wall boundary, and at any predetermined position from that location to within ~ 3/8-in. of the opposite wall.

   b. Accuracy: It shall be capable of programmed positioning to within ~ 1/16-in. of the designated location.

4. Pitot-static differential pressure and air temperature measurements shall be concurrently obtained at incremental locations with two separate probes side-by-side; the pitot-static probes shall extend upstream from the shielded-thermocouple probe to minimize perturbance of the air flow associated with the shielded TC head.

5. The traversing mechanism shall be stably mounted with reference to the duct wall, but located beyond the outside surface of the

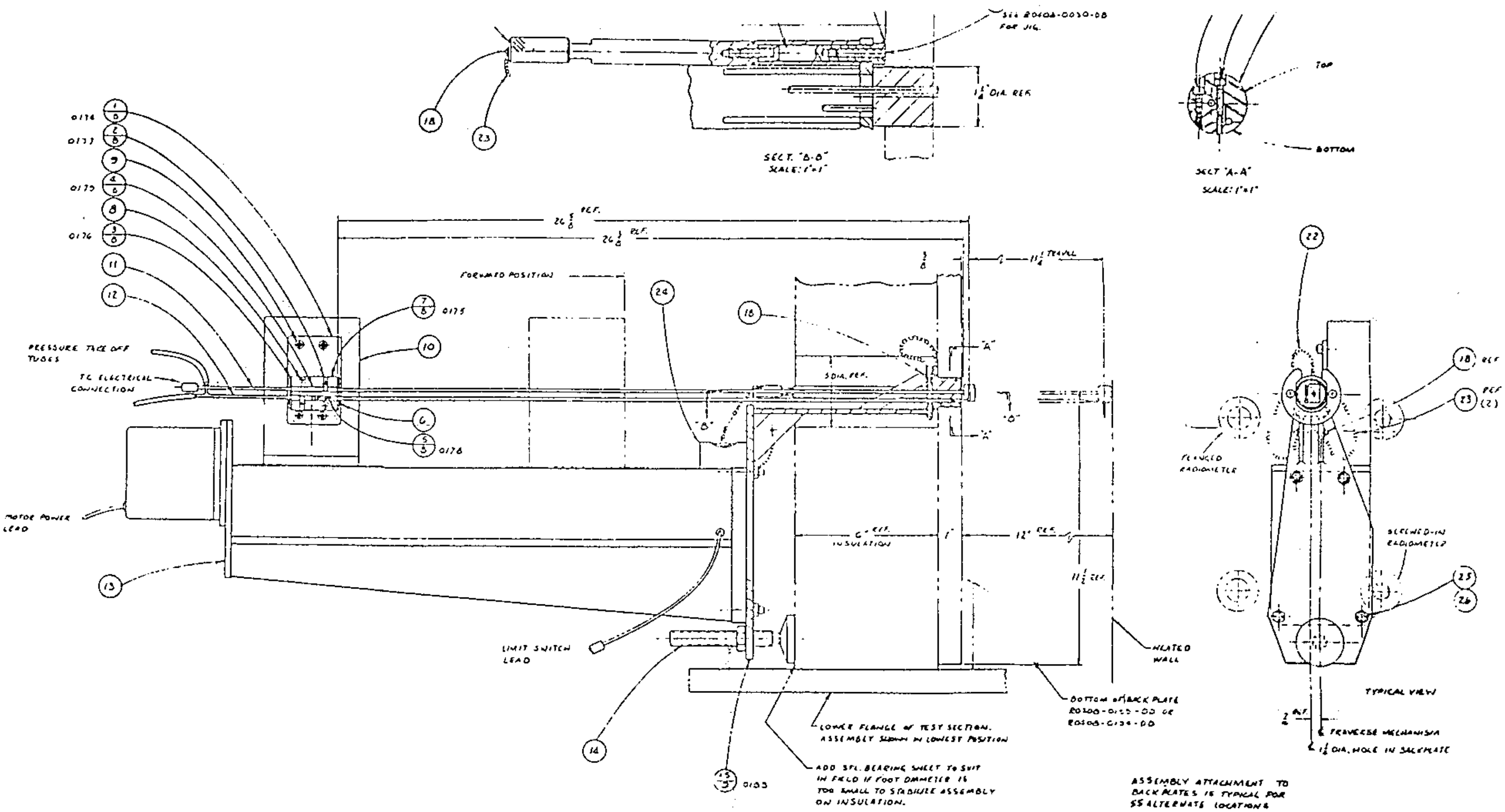


Figure 3-35. Traverse Mechanism Assembly (ANL Dwg. No. R0408-0031-DD).

insulation on the duct wall. This presupposes the following conditions and ramifications:

a. The minimum amount of insulation shall be removed for ingress to a port hole.

b. All port holes will be plugged when not being used; therefore, access holes through the insulation need to be provided for ingress into port holes. Those holes shall be plugged with insulation when not in use.

c. Leveling indicator and adjustment shall be provided.

d. The traversing mechanism shall accommodate the pitot-static and shielded thermocouple probe of the dimensions shown in Fig. 28 for side-by-side insertion and operation.

3.3.7 Wind Monitor and Humidity Instrumentation

The wind speed, direction, and temperature will be continually monitored at about 1-min. time intervals during the performance of a test. If it appears that experiment data anomalies are related to changing meteorological conditions procedures will be devised to account for these effects, perhaps by rerunning selected tests during selected meteorological conditions and/or utilizing alternate exit weather-hood design.

The R. M. Young Company Wind Monitor Model 05305 will be used to determine the wind speed and azimuth wind direction.[43] The wind speed sensor is a helicoid shaped propeller molded of polypropylene plastic. The propeller has four blades, 18-cm. diameter x 30-cm. pitch, with a distance constant of 3.3-m. (10.5-ft.). Threshold sensitivity of the propeller is 0.7-m/s (1.6-mph). Rotation of the propeller produces an AC sine wave voltage signal with frequency directly proportional to wind speed. The AC voltage signal is induced in a centrally mounted coil by a six pole magnet mounted on the propeller shaft. The vane assembly has a threshold sensitivity of 1.0-m/s (2.2-mph) with a damping ratio of 0.23. Vane position is transmitted through a coupling to a precision conductive plastic potentiometer, which is located in a sealed chamber in the center of the main housing just below the wind speed transducer coil. An excitation voltage is supplied to the potentiometer, and the output signal is an analog voltage directly proportional to azimuth angle. Appendix B supplies calibration curves and other pertinent information.

Humidity Instrument

Humidity measurements will be obtained with a Kane-May HP40 humidity-temperature probe, which has a flange-mount attached for mounting in the open air flow to the entrance about 6-ft. away from the entrance section. The probe is designed to measure both dry-bulb temperature and relative humidity. It provides two output signals representing 0 to 100°C, and 0 to 100% RH. The probe requires either 240 V or 110 V, 50-60 Hz power supply. The instrument has been calibration checked, the result of which indicates that it is somewhat slow to respond, and its accuracy is about ± 4% rather than the ± 2% claimed.[44,45]

3.4 Data Acquisition and Computer Control

This section describes the data acquisition and control capabilities of the RVACS/RACS control console.

The control console contains a PDP-11/23 computer, a 30 MB Winchester disk, a floppy disk drive, three Doric data loggers, a CAMAC (Computer Automated Measurement And Control) crate, and two MKS high precision pressure measuring devices. Each Doric data logger, capable of accepting 99 analog input signals, is connected to the computer via a standard RS232 interface. A Doric converts thermocouple inputs to Deg F, but other inputs must be converted by the computer from millivolts to engineering units. The CAMAC system contains modules for digital input, digital output, analog input, and stepping motor control.

Table 3-7. Kane-May HP40 Humidity-Temperature Instrument Specifications

1. SENSORS:	Type-C5 thin film capacitor for RH. Type-PT100 RTD resistance temperature sensor
2. RANGE:	0 to 98% RH 0 to 100°C (14°F - 212°F)
3. ACCURACY:	± 3% RH ± 0.5°C
4. POWER SUPPLY:	110/240 V ± 10%, 50-60 Hz, 3-watts
5. HUMIDITY OUTPUT:	4-20 mA into 1K DC for 0-100% RH
6. TEMPERATURE OUTPUT:	4-20 mA into 1K DC for 0-100°C

The computer provides three principle functions:

- Probe Control and Data Acquisition.
- Doric Data Acquisition and Heater Control.
- Data Analysis and Display.

3.4.1 Probe Control and Data Acquisition

The computer controls and accepts data from the probes via the CAMAC system. During a particular test a probe will be used to collect data from a set of access ports. At each access port the probe will be positioned at various positions within the duct. At each position analog signals will be sampled, e.g. a temperature and a flow. The experimenter must determine the port locations and positions within each port. This information is given to a probe control program which performs the following functions at each port location:

- It instructs the operator to mount the probe at the proper port location. When the probe is properly mounted the operator notifies the probe control program.
- The probe is positioned, via the CAMAC stepping motor control module, to each experimenter determined position.
- The sensors attached to the probe are sampled via the CAMAC analog input module.

3.4.2 Doric Data Acquisition and Heater Control

A data acquisition and heater control program runs at periodic time intervals, e.g. every minute. The first task performed by this program is to sample the signals connected to the Doric data loggers. It should be noted that it takes each data logger about 30 seconds to sample all 99 channels and send the data to the computer. The computer samples all three data loggers simultaneously, but the shortest time for a complete Doric data acquisition and control cycle will be close to one minute.

The next task performed is heater control. From the point of view of control, each two foot test section contains two heaters. The 16 center heaters in each section are controlled via a single control signal, and the four edge heaters also controlled via a single control signal. Thus the entire test vehicle appears to the computer as a collection of two heaters.

The computer treats each heater separately. It controls each heater via two CAMAC control signals: a trip signal, and a unidriver setting. The trip signal is a switch that prevents a heater from being turned on. The unidriver setting is a number specifying the percentage of AC line cycles allowed to flow to the heater. Before a heater receives power three conditions must be met: the trip signal must be in the untripped state, a non-zero unidriver setting must be provided, and the manual heater switch placed in the on position.

For each heater a set of trip thermocouples and a trip temperature can be specified. If any trip thermocouple exceeds the trip temperature the heater is tripped, i.e. power is prevented from flowing to the heater. This is a safety precaution and should not normally occur.

For each heater a set of control thermocouples can be specified. The control temperature is defined as the average of the control thermocouples. The type of control can be any of the following:

- Constant Temperature. The control temperature is maintained at a specified setpoint.

- Match. The control temperature of a heater is maintained so that it equals the control temperature of another heater. This is normally used to make the edge heaters maintain the same control temperature as the main heaters.

- Constant Unidriver Setting.

- Constant Power. The heater provides a constant power input. This is nearly identical to constant unidriver setting. Constant power takes into consideration the resistance of the heater.

It should be noted that unidriver values are only allowed to vary within experimenter determined limits.

After the heater control functions are complete, the data acquisition and heater control program stores the newly obtained set of data into a file. It also notifies all dynamic program that a new set of data is available.

3.4.3 Data Analysis and Display

Data analysis is described in Section 5.0 of this report, thus, this section will only describe data display.

Two display programs are available for monitoring the heater control system: HCL and HCP. HCL provides CRT or hard copy displays showing the current status of the heater control variables. HCP provides a graphical display of various heater control variables.

A number of general purpose display programs are available for displaying data collected by the data acquisition system. The most useful for RVACS/RACS are:

1. Multiple Parameter List - This program provides a listing of data for an arbitrary set of parameters for an arbitrary time period.

2. Multiple Parameter Plot - This program provides a time history plot of data for one or more parameters for an arbitrary time interval.

3. Multiple Parameter Profile Plot - This program plots data collected at a particular time vs. user specified values. For example, a plot of temperature distribution along the test vehicle can be generated.

3.4.4 DAS Recorded Test Parameters

This section first supplies information about the naming convention for thermocouples, heating elements and access ports. That information is given in the following tables:

* Table 3-8. Heated Zone Thermocouple Naming Convention.
* Table 3-9. Inlet Thermocouple Naming Convention.
* Table 3-10. Exit Rake Thermocouple Naming Convention.
* Table 3-11. Chimney Thermocouple Naming Convention.
* Table 3-12. Heating Element Naming Convention.
* Table 3-13. Access Port Naming Convention.

Secondly, this section supplies the DAS identification (PNUM, PID), the parameter units (PUNITS), and the parameter title and description (PTITLE) for every DAS parameter. The DAS parameters consists of measured, calculated, and specified data, and are categorically organized in the following tables:

* Table 3-14. DAS Measured, Calculated, and Specified Utility Parameter List.
* Table 3-15. DAS Thermocouple ID and Location Parameters List.
* Table 3-16. DAS Access Port ID and Location Parameters List.
* Table 3-17. DAS Heater Element ID and Resistance List.
* Table 3-18. DAS Series and Parallel Heater String ID and Resistance List.

Table 3-8. Heated Zone Thermocouple Naming Convention

T	- Thermocouple
xx	- Heater zone (elevation 01 to 10)
D	- Duct wall
O	- Outside
C	- Center
N	- North
S	- South
y	- Elevation within zone, numbered 1 to 4 from bottom
G	- Guard vessel wall
E	- Edge
O	- Outside
C	- Center
N	- North
S	- South
y	- Elevation within zone, numbered 1 to 4 from bottom
D	- Differential, i.e. on plate side of Guard Vessel Wall
F	- Fins (No thermocouples of this type at this time)
H	- Heater
C	- Center
N	- North
S	- South
E	- Edge
N	- North
S	- South
O	- Outside
I	- Inside
S	- Side Wall
N	- North
S	- South
y	- Elevation within zone

Table 3-9. Inlet Thermocouple Naming Convention

T	- Thermocouple
IN	- Inlet
ON	- Outside North
CN	- Center North
CS	- Center South
OS	- Outside South

Table 3-10. Exit Rake Thermocouple Naming Convention

T	- Thermocouple
EX	- Exit
ON	- Outside North
CN	- Center North
CS	- Center South
OS	- Outside South

Table 3-11. Chimney Thermocouple Naming Convention

T	- Thermocouple
CHM	- Chimney
N	- North
S	- South
E	- East
W	- West
0	- At Top
-2	- 2 Feet Below Top
-4	- 4 Feet Below Top

Table 3-12. Heating Element Naming Convention

H	- Heating Element
xx	- Heater Zone (elevation 01 to 10)
C	- Center
O	- Outside
E	- Edge
N	- North
S	- South
y	- Elevation within zone, number 1 to 4 from bottom

Table 3-13. Access Port Naming Convention

P	- Port
xx	- Zone (elevation 01 to 10)
S	- Side Wall
N	- North
S	- South
D	- Duct Wall
y	- Location across zone 1 to 9 from North
RAD	- Radiation Detector
FLUX	- Heat Flux Detector

Table 3-14. DAS Measured, Calculated, and Specified Utility Parameter List DATE: 16-OCT-86

PNUM	PID	PUNITS	PTITLE
1	UNI01M	-	Unidriver value, Zone 01, Main Heater
2	UNI02M	-	Unidriver value, Zone 02, Main Heater
3	UNI03M	-	Unidriver value, Zone 03, Main Heater
4	UNI04M	-	Unidriver value, Zone 04, Main Heater
5	UNI05M	-	Unidriver value, Zone 05, Main Heater
6	UNI06M	-	Unidriver value, Zone 06, Main Heater
7	UNI07M	-	Unidriver value, Zone 07, Main Heater
8	UNI08M	-	Unidriver value, Zone 08, Main Heater
9	UNI09M	-	Unidriver value, Zone 09, Main Heater
10	UNI10M	-	Unidriver value, Zone 10, Main Heater
21	UNI01E	-	Unidriver value, Zone 01, Edge Heater
22	UNI02E	-	Unidriver value, Zone 02, Edge Heater
23	UNI03E	-	Unidriver value, Zone 03, Edge Heater
24	UNI04E	-	Unidriver value, Zone 04, Edge Heater
25	UNI05E	-	Unidriver value, Zone 05, Edge Heater
26	UNI06E	-	Unidriver value, Zone 06, Edge Heater
27	UNI07E	-	Unidriver value, Zone 07, Edge Heater
28	UNI08E	-	Unidriver value, Zone 08, Edge Heater
29	UNI09E	-	Unidriver value, Zone 09, Edge Heater
30	UNI10E	-	Unidriver value, Zone 10, Edge Heater
41	PWR01M	Kw	Power, Zone 01, Main Heater
42	PWR02M	Kw	Power, Zone 02, Main Heater
43	PWR03M	Kw	Power, Zone 03, Main Heater
44	PWR04M	Kw	Power, Zone 04, Main Heater
45	PWR05M	Kw	Power, Zone 05, Main Heater
46	PWR06M	Kw	Power, Zone 06, Main Heater
47	PWR07M	Kw	Power, Zone 07, Main Heater
48	PWR08M	Kw	Power, Zone 08, Main Heater
49	PWR09M	Kw	Power, Zone 09, Main Heater
50	PWR10M	Kw	Power, Zone 10, Main Heater
61	PWR01E	Kw	Power, Zone 01, Edge Heater
62	PWR02E	Kw	Power, Zone 02, Edge Heater
63	PWR03E	Kw	Power, Zone 03, Edge Heater
64	PWR04E	Kw	Power, Zone 04, Edge Heater
65	PWR05E	Kw	Power, Zone 05, Edge Heater
66	PWR06E	Kw	Power, Zone 06, Edge Heater
67	PWR07E	Kw	Power, Zone 07, Edge Heater
68	PWR08E	Kw	Power, Zone 08, Edge Heater
69	PWR09E	Kw	Power, Zone 09, Edge Heater
70	PWR10E	Kw	Power, Zone 10, Edge Heater
81	CTL01M	Deg F	Control Temperature, Zone 01, Main Heater
82	CTL02M	Deg F	Control Temperature, Zone 02, Main Heater
83	CTL03M	Deg F	Control Temperature, Zone 03, Main Heater
84	CTL04M	Deg F	Control Temperature, Zone 04, Main Heater
85	CTL05M	Deg F	Control Temperature, Zone 05, Main Heater
86	CTL06M	Deg F	Control Temperature, Zone 06, Main Heater
87	CTL07M	Deg F	Control Temperature, Zone 07, Main Heater
88	CTL08M	Deg F	Control Temperature, Zone 08, Main Heater

Table 3-14. DAS Measured, Calculated, and Specified Utility Parameter List (cont'd) DATE: 16-OCT-86

PNUM	PID	PUNITS	PTITLE
89	CTL09M	Deg F	Control Temperature, Zone 09, Main Heater
90	CTL10M	Deg F	Control Temperature, Zone 10, Main Heater
101	CTL01E	Deg F	Control Temperature, Zone 01, Edge Heater
102	CTL02E	Deg F	Control Temperature, Zone 02, Edge Heater
103	CTL03E	Deg F	Control Temperature, Zone 03, Edge Heater
104	CTL04E	Deg F	Control Temperature, Zone 04, Edge Heater
105	CTL05E	Deg F	Control Temperature, Zone 05, Edge Heater
106	CTL06E	Deg F	Control Temperature, Zone 06, Edge Heater
107	CTL07E	Deg F	Control Temperature, Zone 07, Edge Heater
108	CTL08E	Deg F	Control Temperature, Zone 08, Edge Heater
109	CTL09E	Deg F	Control Temperature, Zone 09, Edge Heater
110	CTL10E	Deg F	Control Temperature, Zone 10, Edge Heater
121	TOTPWR	Kw	Total Power all Heaters
122	DORIC1	Volts	Doric 1 Self Test
123	DORIC2	Volts	Doric 2 Self Test
124	DORIC3	Volts	Doric 3 Self Test
151	ACA	Volts	Ac Phase A Voltage
152	ACB	Volts	Ac Phase B Voltage
153	ACC	Volts	Ac Phase C Voltage
201	DPEXIT	Torrs	Differential Pressure at Exit (Rake), El: 34'
300	BPRES	psi	Barometric Pressure
301	TAIRIN	Deg F	Tc, Air Temperature Near Inlet
302	TAIROUT	Deg F	Tc, Air Temperature at Weather Tower
303	WVEL	ft/sec	Wind Velocity at Weather Tower
304	WDIR	Deg	Wind Direction at Weather Tower
305	RELHUM	%	Relative Humidity
306	HDTAIR	Deg F	Air Temperature Measured by Humidity Detector
401	HFRAD02	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 02
402	HFRAD04	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 04
403	HFRAD05	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 05
404	HFRAD07	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 07
405	HFRAD08	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 08
406	HFRAD10	B/f2s	Heat Flux From Guard Vessel Wall Radiometer, Zone 10
407	THFRAD02	Deg F	Temperature of Radiometer, Zone 02
408	THFRAD04	Deg F	Temperature of Radiometer, Zone 04
409	THFRAD05	Deg F	Temperature of Radiometer, Zone 05
410	THFRAD07	Deg F	Temperature of Radiometer, Zone 07
411	THFRAD08	Deg F	Temperature of Radiometer, Zone 08
412	THFRAD10	Deg F	Temperature of Radiometer, Zone 10
421	HFEM02	B/f2s	Heat Flux From Emissitivity Probe, Zone 02
422	HFEM04	B/f2s	Heat Flux From Emissitivity Probe, Zone 04
423	HFEM05	B/f2s	Heat Flux From Emissitivity Probe, Zone 05
424	HFEM07	B/f2s	Heat Flux From Emissitivity Probe, Zone 07
425	HFEM08	B/f2s	Heat Flux From Emissitivity Probe, Zone 08
426	HFEM10	B/f2s	Heat Flux From Emissitivity Probe, Zone 10
427	THFEM02	Deg F	Temperature of Emissitivity Probe, Zone 02
428	THFEM04	Deg F	Temperature of Emissitivity Probe, Zone 04
429	THFEM05	Deg F	Temperature of Emissitivity Probe, Zone 05

Table 3-14. DAS Measured, Calculated, and Specified Utility Parameter List (cont'd) DATE: 16-OCT-86

PNUM	PID	PUNITS	PTITLE
430	THFEM07	Deg F	Temperature of Emissitivity Probe, Zone 07
431	THFEM08	Deg F	Temperature of Emissitivity Probe, Zone 08
432	THFEM10	Deg F	Temperature of Emissitivity Probe, Zone 10
441	HFCND02	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 02
442	HFCND04	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 04
443	HFCND05	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 05
444	HFCND07	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 07
445	HFCND08	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 08
446	HFCND10	B/f2s	Heat Flux From Duct Wall Conductivity Probe, Zone 10
441	THFCND02	Deg F	Temperature of Conductivity Probe, Zone 02
441	THFCND04	Deg F	Temperature of Conductivity Probe, Zone 04
441	THFCND05	Deg F	Temperature of Conductivity Probe, Zone 05
441	THFCND07	Deg F	Temperature of Conductivity Probe, Zone 07
441	THFCND08	Deg F	Temperature of Conductivity Probe, Zone 08
441	THFCND10	Deg F	Temperature of Conductivity Probe, Zone 10

Table 3-15. DAS Thermocouple ID and Location Parameters

PNUM	PID	PUNITS	PTITLE
901	TINON	Deg F	Tc, Inlet, Outside North, El: -36""
902	TINCN	Deg F	Tc, Inlet, Center North, El: -36"
903	TINCS	Deg F	Tc, Inlet, Center South, El: -36"
904	TINOS	Deg F	Tc, Inlet, Outside South, El: -36"
911	TEXON	Deg F	Tc, Exit (Rake), Outside North, El: 34'
912	TEXCN	Deg F	Tc, Exit (Rake), Center North, El: 34'
914	TEXCS	Deg F	Tc, Exit (Rake), Center South, El: 34'
915	TEXOS	Deg F	Tc, Exit (Rake), Outside South, El: 34'
950	TCHMNO	Deg F	Tc, Chimney, North Side, Top
951	TCHMN-2	Deg F	Tc, Chimney, North Side, 2' below Top
952	TCHMN-4	Deg F	Tc, Chimney, North Side, 4' below Top
953	TCHMSO	Deg F	Tc, Chimney, South Side, Top
954	TCHMS-2	Deg F	Tc, Chimney, South Side, 2' below Top
955	TCHMS-4	Deg F	Tc, Chimney, South Side, 4' below Top
956	TCHMEO	Deg F	Tc, Chimney, East Side, Top
957	TCHME-2	Deg F	Tc, Chimney, East Side, 2' below Top
958	TCHME-4	Deg F	Tc, Chimney, East Side, 4' below Top
959	TCHMWO	Deg F	Tc, Chimney, West Side, Top
960	TCHMW-2	Deg F	Tc, Chimney, West Side, 2' below Top
961	TCHMW-4	Deg F	Tc, Chimney, West Side, 4' below Top
1001	T01GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 5"
1002	T01GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 5"
1003	T01GON2	Deg F	Tc, Guard vessel wall, Outside, North, El: 11"
1004	T01GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 11"
1005	T01GCN2D	Deg F	Diff Tc, Guard vessel wall, Center, North, El: 11"
1006	T01GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 11"
1007	T01GOS2	Deg F	Tc, Guard vessel wall, Outside, South, El: 11"
1008	T01GCN3	Deg F	Tc, Guard vessel wall, Center, North, El: 17"
1009	T01GCS3	Deg F	Tc, Guard vessel wall, Center, South, El: 17"
1010	T01GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 23"
1011	T01GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 23"
1012	T01GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 8"
1013	T01GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 20"
1014	T01GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 8"
1015	T01GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 20"
1016	T01DCN1	Deg F	Tc, Duct wall, Center, North, El: 5"
1017	T01DCS1	Deg F	Tc, Duct wall, Center, South, El: 5"
1018	T01DON2	Deg F	Tc, Duct wall, Outside, North, El: 11"
1019	T01DCN2	Deg F	Tc, Duct wall, Center, North, El: 11"
1020	T01DCS2	Deg F	Tc, Duct wall, Center, South, El: 11"
1021	T01DOS2	Deg F	Tc, Duct wall, Outside, South, El: 11"
1022	T01DCN3	Deg F	Tc, Duct wall, Center, North, El: 17"
1023	T01DCS3	Deg F	Tc, Duct wall, Center, South, El: 17"
1024	T01DCN4	Deg F	Tc, Duct wall, Center, North, El: 23"
1025	T01DCS4	Deg F	Tc, Duct wall, Center, South, El: 23"
1026	T01SN2	Deg F	Tc, Side wall, North,. El: 11"
1027	T01SS2	Deg F	Tc, Side wall, South, El: 11"
1028	T01HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 14"
1029	T01HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 14"

Table 3-15. DAS Thermocouple ID and Location Parameters (cont'd)

PNUM	PID	PUNITS	PTITLE
1030	T01HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 14"
1031	T01HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 14"
1032	T01HCN	Deg F	Tc, Heater, Center, North, El: 14"
1033	T01HCS	Deg F	Tc, Heater, Center, South, El: 14"
1101	T02GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 31"
1102	T02GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 31"
1103	T02GON2	Deg F	Tc, Guard vessel wall, Outside, North, El: 37"
1104	T02GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 37"
1105	T02GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 37"
1106	T02GCS2D	Deg F	Diff Tc, Guard vessel wall, Center, South, El: 37"
1107	T02GOS2	Deg F	Tc, Guard vessel wall, Outside, South, El: 37"
1108	T02GCN3	Deg F	Tc, Guard vessel wall, Center, North, El: 43"
1109	T02GCS3	Deg F	Tc, Guard vessel wall, Center, South, El: 43"
1110	T02GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 49"
1111	T02GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 49"
1112	T02GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 34"
1113	T02GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 46"
1114	T02GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 34"
1115	T02GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 46"
1116	T02DCN1	Deg F	Tc, Duct wall, Center, North, El: 31"
1117	T02DCS1	Deg F	Tc, Duct wall, Center, South, El: 31"
1118	T02DON2	Deg F	Tc, Duct wall, Outside, North, El: 37"
1119	T02DCN2	Deg F	Tc, Duct wall, Center, North, El: 37"
1120	T02DCS2	Deg F	Tc, Duct wall, Center, South, El: 37"
1121	T02DOS2	Deg F	Tc, Duct wall, Outside, South, El: 37"
1122	T02DCN3	Deg F	Tc, Duct wall, Center, North, El: 43"
1123	T02DCS3	Deg F	Tc, Duct wall, Center, South, El: 43"
1124	T02DCN4	Deg F	Tc, Duct wall, Center, North, El: 49"
1125	T02DCS4	Deg F	Tc, Duct wall, Center, South, El: 49"
1126	T02SN2	Deg F	Tc, Side wall, North, El: 37"
1127	T02SS2	Deg F	Tc, Side wall, South, El: 37"
1128	T02HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 40"
1129	T02HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 40"
1130	T02HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 40"
1131	T02HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 40"
1132	T02HCN	Deg F	Tc, Heater, Center, North, El: 40"
1133	T02HCS	Deg F	Tc, Heater, Center, South, El: 40"
1201	T03GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 57"
1202	T03GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 57"
1203	T03GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 63"
1204	T03GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 63"
1205	T03GON3	Deg F	Tc, Guard vessel wall, Outside, North, El: 69"
1206	T03GCN3	Deg F	Tc, Guard vessel wall, Center, North, El: 69"
1207	T03GCN3D	Deg F	Diff Tc, Guard vessel wall, Center, North, El: 69"
1208	T03GCS3	Deg F	Tc, Guard vessel wall, Center, South, El: 69"
1209	T03GOS3	Deg F	Tc, Guard vessel wall, Outside, South, El: 69"
1210	T03GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 75"
1211	T03GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 75"

Table 3-15. DAS Thermocouple ID and Location Parameters (cont'd)

PNUM	PID	PUNITS	PTITLE
1212	T03GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 60"
1213	T03GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 72"
1214	T03GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 60"
1215	T03GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 72"
1216	T03DCN1	Deg F	Tc, Duct wall, Center, North, El: 57"
1217	T03DCS1	Deg F	Tc, Duct wall, Center, South, El: 57"
1218	T03DCN2	Deg F	Tc, Duct wall, Center, North, El: 63"
1219	T03DCS2	Deg F	Tc, Duct wall, Center, South, El: 63"
1220	T03DON3	Deg F	Tc, Duct wall, Outside, North, El: 69"
1221	T03DCN3	Deg F	Tc, Duct wall, Center, North, El: 69"
1222	T03DCS3	Deg F	Tc, Duct wall, Center, South, El: 69"
1223	T03DOS3	Deg F	Tc, Duct wall, Outside, South, El: 69"
1224	T03DCN4	Deg F	Tc, Duct wall, Center, North, El: 75"
1225	T03DCS4	Deg F	Tc, Duct wall, Center, South, El: 75"
1226	T03SN3	Deg F	Tc, Side wall, North, El: 69"
1227	T03SS3	Deg F	Tc, Side wall, South, El: 69"
1228	T03HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 66"
1229	T03HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 66"
1230	T03HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 66"
1231	T03HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 66"
1232	T03HCN	Deg F	Tc, Heater, Center, North, El: 66"
1233	T03HCS	Deg F	Tc, Heater, Center, South, El: 66"
1301	T04GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 83"
1302	T04GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 83"
1303	T04GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 89"
1304	T04GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 89"
1305	T04GCN3	Deg F	Tc, Guard vessel wall, Center, North, El: 95"
1306	T04GCS3	Deg F	Tc, Guard vessel wall, Center, South, El: 95"
1307	T04GCS3D	Deg F	Diff Tc, Guard vessel wall, Center, South, El: 95"
1308	T04GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 101"
1309	T04GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 101"
1310	T04GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 86"
1311	T04GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 98"
1312	T04GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 86"
1313	T04GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 98"
1314	T04DCN1	Deg F	Tc, Duct wall, Center, North, El: 83"
1315	T04DCS1	Deg F	Tc, Duct wall, Center, South, El: 83"
1316	T04DCN2	Deg F	Tc, Duct wall, Center, North, El: 89"
1317	T04DCS2	Deg F	Tc, Duct wall, Center, South, El: 89"
1318	T04DCN3	Deg F	Tc, Duct wall, Center, North, El: 95"
1319	T04DCS3	Deg F	Tc, Duct wall, Center, South, El: 95"
1320	T04DCN4	Deg F	Tc, Duct wall, Center, North, El: 101"
1321	T04DCS4	Deg F	Tc, Duct wall, Center, South, El: 101"
1322	T04HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 92"
1323	T04HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 92"
1324	T04HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 92"
1325	T04HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 92"
1326	T04HCN	Deg F	Tc, Heater, Center, North, El: 92"

Table 3-15. DAS Thermocouple ID and Location Parameters (cont'd)

PNUM	PID	PUNITS	PTITLE
1327	T04HCS	Deg F	Tc, Heater, Center, South, El: 92"
1401	T05GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 109"
1402	T05GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 109"
1403	T05GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 115"
1404	T05GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 115"
1405	T05GON3	Deg F	Tc, Guard vessel wall, Outside, North, El: 121"
1406	T05GCN3	Deg F	Tc, Guard vessel wall, Center, North, El: 121"
1407	T05GCN3D	Deg F	Diff Tc, Guard vessel wall, Center, North, El: 121"
1408	T05GCS3	Deg F	Tc, Guard vessel wall, Center, South, El: 121"
1409	T05GOS3	Deg F	Tc, Guard vessel wall, Outside, South, El: 121"
1410	T05GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 127"
1411	T05GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 127"
1412	T05GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 112"
1413	T05GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 124"
1414	T05GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 112"
1415	T05GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 124"
1416	T05DCN1	Deg F	Tc, Duct wall, Center, North, El: 109"
1417	T05DCS1	Deg F	Tc, Duct wall, Center, South, El: 109"
1418	T05DCN2	Deg F	Tc, Duct wall, Center, North, El: 115"
1419	T05DCS2	Deg F	Tc, Duct wall, Center, South, El: 115"
1420	T05DON3	Deg F	Tc, Duct wall, Outside, North, El: 121"
1421	T05DCN3	Deg F	Tc, Duct wall, Center, North, El: 121"
1422	T05DCS3	Deg F	Tc, Duct wall, Center, South, El: 121"
1423	T05DOS3	Deg F	Tc, Duct wall, Outside, South, El: 121"
1424	T05DCN4	Deg F	Tc, Duct wall, Center, North, El: 127"
1425	T05DCS4	Deg F	Tc, Duct wall, Center, South, El: 127"
1426	T05SN3	Deg F	Tc, Side wall, North, El: 121"
1427	T05SS3	Deg F	Tc, Side wall, South, El: 121"
1428	T05HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 118"
1429	T05HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 118"
1430	T05HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 118"
1431	T05HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 118"
1432	T05HCN	Deg F	Tc, Heater, Center, North, El: 118"
1433	T05HCS	Deg F	Tc, Heater, Center, South, El: 118"
1501	T06GCN1	Deg F	Tc, Guard vessel wall, Center, North, El: 140"
1502	T06GCS1	Deg F	Tc, Guard vessel wall, Center, South, El: 140"
1503	T06GON2	Deg F	Tc, Guard vessel wall, Outside, North, El: 146"
1504	T06GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 146"
1505	T06GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 146"
1506	T06GCS2D	Deg F	Diff Tc, Guard vessel wall, Center, South, El: 146"
1507	T06GOS2	Deg F	Tc, Guard vessel wall, Outside, South, El: 146"
1508	T06GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 158"
1509	T06GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 158"
1510	T06GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 143"
1511	T06GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 155"
1512	T06GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 143"
1513	T06GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 155"
1514	T06DCN1	Deg F	Tc, Duct wall, Center, North, El: 140"
1515	T06DCS1	Deg F	Tc, Duct wall, Center, South, El: 140"

Table 3-15. DAS Thermocouple ID and Location Parameters (cont'd)

PNUM	PID	PUNITS	PTITLE
1516	T06DON2	Deg F	Tc, Duct wall, Outside, North, El: 146"
1517	T06DCN2	Deg F	Tc, Duct wall, Center, North, El: 146"
1518	T06DCS2	Deg F	Tc, Duct wall, Center, South, El: 146"
1519	T06DOS2	Deg F	Tc, Duct wall, Outside, South, El: 146"
1520	T06DCN4	Deg F	Tc, Duct wall, Center, North, El: 158"
1521	T06DCS4	Deg F	Tc, Duct wall, Center, South, El: 158"
1522	T06SN2	Deg F	Tc, Side wall, North, El: 146"
1523	T06SS2	Deg F	Tc, Side wall, South, El: 146"
1524	T06HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 149"
1525	T06HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 149"
1526	T06HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 149"
1527	T06HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 149"
1528	T06HCN	Deg F	Tc, Heater, Center, North, El: 149"
1529	T06HCS	Deg F	Tc, Heater, Center, South, El: 149"
1601	T07GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 172"
1602	T07GCN2D	Deg F	Diff Tc, Guard vessel wall, Center, North, El: 172"
1603	T07GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 172"
1604	T07GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 184"
1605	T07GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 184"
1606	T07GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 169"
1607	T07GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 181"
1608	T07GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 169"
1609	T07GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 181"
1610	T07DCN2	Deg F	Tc, Duct wall, Center, North, El: 172"
1611	T07DCS2	Deg F	Tc, Duct wall, Center, South, El: 172"
1612	T07DCN4	Deg F	Tc, Duct wall, Center, North, El: 184"
1613	T07DCS4	Deg F	Tc, Duct wall, Center, South, El: 184"
1614	T07HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 175"
1615	T07HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 175"
1616	T07HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 175"
1617	T07HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 175"
1618	T07HCN	Deg F	Tc, Heater, Center, North, El: 175"
1619	T07HCS	Deg F	Tc, Heater, Center, South, El: 175"
1701	T08GON2	Deg F	Tc, Guard vessel wall, Outside, North, El: 198"
1702	T08GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 198"
1703	T08GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 198"
1704	T08GCS2D	Deg F	Diff Tc, Guard vessel wall, Center, South, El: 198"
1705	T08GOS2	Deg F	Tc, Guard vessel wall, Outside, South, El: 198"
1706	T08GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 210"
1707	T08GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 210"
1708	T08GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 195"
1709	T08GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 207"
1710	T08GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 195"
1711	T08GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 207"
1712	T08DON2	Deg F	Tc, Duct wall, Outside, North, El: 198"
1713	T08DCN2	Deg F	Tc, Duct wall, Center, North, El: 198"
1714	T08DCS2	Deg F	Tc, Duct wall, Center, South, El: 198"
1715	T08DOS2	Deg F	Tc, Duct wall, Outside, South, El: 198"
1716	T08DCN4	Deg F	Tc, Duct wall, Center, North, El: 210"
1717	T08DCS4	Deg F	Tc, Duct wall, Center, South, El: 210"
1718	T08SN2	Deg F	Tc, Side wall, North, El: 198"
1719	T08SS2	Deg F	Tc, Side wall, South, El: 198"

Table 3-15. DAS Thermocouple ID and Location Parameters (cont'd)

PNUM	PID	PUNITS	PTITLE
1720	T08HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 201"
1721	T08HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 201"
1722	T08HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 201"
1723	T08HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 201"
1724	T08HCN	Deg F	Tc, Heater, Center, South, El: 201"
1725	T08HCS	Deg F	Tc, Heater, Center, South, El: 201"
1801	T09GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 224"
1802	T09GCN2D	Deg F	Diff Tc, Guard vessel wall, Center, North, El: 224"
1803	T09GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 224"
1804	T09GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 236"
1805	T09GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 236"
1806	T09GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 221"
1807	T09GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 233"
1808	T09GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 221"
1809	T09GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 233"
1810	T09DCN2	Deg F	Tc, Duct wall, Center, North, El: 224"
1811	T09DCS2	Deg F	Tc, Duct wall, Center, South, El: 224"
1812	T09DCN4	Deg F	Tc, Duct wall, Center, North, El: 236"
1813	T09DCS4	Deg F	Tc, Duct wall, Center, South, El: 236"
1814	T09HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 227"
1815	T09HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 227"
1816	T09HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 227"
1817	T09HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 227"
1818	T09HCN	Deg F	Tc, Heater, Center, North, El: 227"
1819	T09HCS	Deg F	Tc, Heater, Center, South, El: 227"
1901	T10GCN2	Deg F	Tc, Guard vessel wall, Center, North, El: 250"
1902	T10GCS2	Deg F	Tc, Guard vessel wall, Center, South, El: 250"
1903	T10GON4	Deg F	Tc, Guard vessel wall, Outside, North, El: 262"
1904	T10GCN4	Deg F	Tc, Guard vessel wall, Center, North, El: 262"
1905	T10GCS4	Deg F	Tc, Guard vessel wall, Center, South, El: 262"
1906	T10GCS4D	Deg F	Diff Tc, Guard vessel wall, Center, South, El: 262"
1907	T10GOS4	Deg F	Tc, Guard vessel wall, Outside, South, El: 262"
1908	T10GEN1	Deg F	Tc, Guard vessel wall, Edge, North, El: 247"
1909	T10GEN2	Deg F	Tc, Guard vessel wall, Edge, North, El: 259"
1910	T10GES1	Deg F	Tc, Guard vessel wall, Edge, South, El: 247"
1911	T10GES2	Deg F	Tc, Guard vessel wall, Edge, South, El: 259"
1912	T10DCN2	Deg F	Tc, Duct wall, Center, North, El: 250"
1913	T10DCS2	Deg F	Tc, Duct wall, Center, South, El: 250"
1914	T10DON4	Deg F	Tc, Duct wall, Outside, North, El: 262"
1915	T10DCN4	Deg F	Tc, Duct wall, Center, North, El: 262"
1916	T10DCS4	Deg F	Tc, Duct wall, Center, South, El: 262"
1917	T10DOS4	Deg F	Tc, Duct wall, Outside, South, El: 262"
1918	T10SN4	Deg F	Tc, Side wall, North, El: 262"
1919	T10SS4	Deg F	Tc, Side wall, South, El: 262"
1920	T10HENO	Deg F	Tc, Heater, Edge, North, Outside, El: 253"
1921	T10HENI	Deg F	Tc, Heater, Edge, North, Inside, El: 253"
1922	T10HESO	Deg F	Tc, Heater, Edge, South, Outside, El: 253"
1923	T10HESI	Deg F	Tc, Heater, Edge, South, Inside, El: 253"
1924	T10HCN	Deg F	Tc, Heater, Center, North, El: 253"
1925	T10HCS	Deg F	Tc, Heater, Center, South, El: 253"

Table 3-16. DAS Access Port ID and Location Parameter List

Note #1. "El" locations are referenced from bottom flange of the Test Section Weldment.

Note #2. "X:" Duct wall hole locations are referenced from the North-West edge of the Duct Wall.

Note #3. "X:" for Side Wall hole locations are referenced from the South-West corner of the Duct Wall.

PNUM	PID	PTITLE
4012	P01D2	Access Port, Zone 01, El: 12", X: 12"
4014	P01D4	Access Port, Zone 01, El: 12", X: 24"
4016	P01D6	Access Port, Zone 01, El: 12", X: 36"
4018	P01D8	Access Port, Zone 01, El: 12", X: 48"
4021	P02D1	Access Port, Zone 02, El: 38", X: 6"
4022	P02D2	Access Port, Zone 02, El: 38", X: 12"
4023	P02D3	Access Port, Zone 02, El: 38", X: 18"
4024	P02D4	Access Port, Zone 02, El: 38", X: 24"
4025	P02D5	Access Port, Zone 02, El: 38", X: 30"
4026	P02D6	Access Port, Zone 02, El: 38", X: 36"
4027	P02D7	Access Port, Zone 02, El: 38", X: 42"
4028	P02D8	Access Port, Zone 02, El: 38", X: 48"
4029	P02D9	Access Port, Zone 02, El: 38", X: 54"
4030	P02SS	Access Port, Zone 02, Side Wall South, El: 38", X: 6"
4032	P03D2	Access Port, Zone 03, El: 70", X: 12"
4034	P03D4	Access Port, Zone 03, El: 70", X: 24"
4036	P03D6	Access Port, Zone 03, El: 70", X: 36"
4038	P03D8	Access Port, Zone 03, El: 70", X: 48"
4042	P04D2	Access Port, Zone 04, El: 96", X: 12"
4044	P04D4	Access Port, Zone 04, El: 96", X: 24"
4046	P04D6	Access Port, Zone 04, El: 96", X: 36"
4048	P04D8	Access Port, Zone 04, El: 96", X: 48"
4050	P04SS	Access Port, Zone 04, Side Wall South, El: 83", X: 6"
4052	P05D2	Access Port, Zone 05, El: 122", X: 12"
4054	P05D4	Access Port, Zone 05, El: 122", X: 24"
4056	P05D6	Access Port, Zone 05, El: 122", X: 36"
4058	P05D8	Access Port, Zone 05, El: 122", X: 48"
4060	P05SS	Access Port, Zone 05, Side Wall South, El: 122", X: 6"
4062	P06D2	Access Port, Zone 06, El: 147", X: 12"
4064	P06D4	Access Port, Zone 06, El: 147", X: 24"
4066	P06D6	Access Port, Zone 06, El: 147", X: 36"
4068	P06D8	Access Port, Zone 06, El: 147", X: 48"
4072	P07D2	Access Port, Zone 07, El: 173", X: 12"
4074	P07D4	Access Port, Zone 07, El: 173", X: 24"
4076	P07D6	Access Port, Zone 07, El: 173", X: 36"
4078	P07D8	Access Port, Zone 07, El: 173", X: 48"
4080	P07SS	Access Port, Zone 07, Side Wall South, El: 173", X: 6"
4081	P08D1	Access Port, Zone 08, El: 199", X: 6"
4082	P08D2	Access Port, Zone 08, El: 199", X: 12"
4083	P08D3	Access Port, Zone 08, El: 199", X: 18"
4084	P08D4	Access Port, Zone 08, El: 199", X: 24"
4085	P08D5	Access Port, Zone 08, El: 199", X: 30"
4086	P08D6	Access Port, Zone 08, El: 199", X: 36"
4087	P08D7	Access Port, Zone 08, El: 199", X: 42"
4088	P08D8	Access Port, Zone 08, El: 199", X: 48"
4089	P08D9	Access Port, Zone 08, El: 199", X: 54"
4090	P08SS	Access Port, Zone 08, Side Wall South, El: 199", X: 6"
4092	P09D2	Access Port, Zone 09, El: 225", X: 12"

Table 3-16. DAS Access Port ID and Location Parameter List (cont'd)

PNUM	PID	PTITLE
4094	P09D4	Access Port, Zone 09, El: 225", X: 24"
4096	P09D6	Access Port, Zone 09, El: 225", X: 36"
4098	P09D8	Access Port, Zone 09, El: 225", X: 48"
4101	P10D1	Access Port, Zone 10, El: 263", X: 6"
4102	P10D2	Access Port, Zone 10, El: 263", X: 12"
4103	P10D3	Access Port, Zone 10, El: 263", X: 18"
4104	P10D4	Access Port, Zone 10, El: 263", X: 24"
4105	P10D5	Access Port, Zone 10, El: 263", X: 30"
4106	P10D6	Access Port, Zone 10, El: 263", X: 36"
4107	P10D7	Access Port, Zone 10, El: 263", X: 42"
4108	P10D8	Access Port, Zone 10, El: 263", X: 48"
4109	P10D9	Access Port, Zone 10, El: 263", X: 54"
4110	P10SS	Access Port, Zone 10, Side Wall South, El: 263", X: 6"
4201	P02RAD	Radiometer Access Port, Zone 02, El: 37", X: 27"
4202	P04RAD	Radiometer Access Port, Zone 04, El: 83", X: 27"
4203	P05RAD	Radiometer Access Port, Zone 05, El: 121", X: 27"
4204	P07RAD	Radiometer Access Port, Zone 07, El: 172", X: 27"
4205	P08RAD	Radiometer Access Port, Zone 08, El: 198", X: 27"
4206	P10RAD	Radiometer Access Port, Zone 10, El: 250", X: 27"
4211	P02FLUX	Heat Flux Detector Access Port, Zone 02, El: 37", X: 33"
4212	P04FLUX	Heat Flux Detector Access Port, Zone 04, El: 83", X: 33"
4213	P05FLUX	Heat Flux Detector Access Port, Zone 05, El: 121", X: 33"
4214	P07FLUX	Heat Flux Detector Access Port, Zone 07, El: 172", X: 33"
4215	P08FLUX	Heat Flux Detector Access Port, Zone 08, El: 198", X: 33"
4216	P10FLUX	Heat Flux Detector Access Port, Zone 10, El: 250", X: 33"

Table 3-17. DAS Heater Element ID and Resistance List

PNUM	PID	PTITLE	Ohms
3001	H01EN1	Heater, Zone 01, Edge, North, Resistance:	11.844
3002	H01EN2	Heater, Zone 01, Edge, North, Resistance:	12.444
3003	H01ON1	Heater, Zone 01, Outside, North, Resistance:	12.432
3004	H01ON2	Heater, Zone 01, Outside, North, Resistance:	11.811
3005	H01ON3	Heater, Zone 01, Outside, North, Resistance:	11.909
3006	H01ON4	Heater, Zone 01, Outside, North, Resistance:	12.725
3007	H01CN1	Heater, Zone 01, Center, North, Resistance:	11.851
3008	H01CN2	Heater, Zone 01, Center, North, Resistance:	12.432
3009	H01CN3	Heater, Zone 01, Center, North, Resistance:	12.358
3010	H01CN4	Heater, Zone 01, Center, North, Resistance:	11.965
3011	H01CS1	Heater, Zone 01, Center, South, Resistance:	11.549
3012	H01CS2	Heater, Zone 01, Center, South, Resistance:	11.987
3013	H01CS3	Heater, Zone 01, Center, South, Resistance:	11.833
3014	H01CS4	Heater, Zone 01, Center, South, Resistance:	12.158
3015	H01OS1	Heater, Zone 01, Outside, South, Resistance:	12.425
3016	H01OS2	Heater, Zone 01, Outside, South, Resistance:	12.211
3017	H01OS3	Heater, Zone 01, Outside, South, Resistance:	11.935
3018	H01OS4	Heater, Zone 01, Outside, South, Resistance:	12.292
3019	H01ES1	Heater, Zone 01, Edge, South, Resistance:	12.017
3020	H01ES2	Heater, Zone 01, Edge, South, Resistance:	12.025
3021	H02EN1	Heater, Zone 02, Edge, North, Resistance:	12.482
3022	H02EN2	Heater, Zone 02, Edge, North, Resistance:	12.423
3023	H02ON1	Heater, Zone 02, Outside, North, Resistance:	12.485
3024	H02ON2	Heater, Zone 02, Outside, North, Resistance:	12.294
3025	H02ON3	Heater, Zone 02, Outside, North, Resistance:	12.396
3026	H02ON4	Heater, Zone 02, Outside, North, Resistance:	12.156
3027	H02CN1	Heater, Zone 02, Center, North, Resistance:	12.370
3028	H02CN2	Heater, Zone 02, Center, North, Resistance:	11.923
3029	H02CN3	Heater, Zone 02, Center, North, Resistance:	12.385
3030	H02CN4	Heater, Zone 02, Center, North, Resistance:	12.303
3031	H02CS1	Heater, Zone 02, Center, South, Resistance:	12.411
3032	H02CS2	Heater, Zone 02, Center, South, Resistance:	12.466
3033	H02CS3	Heater, Zone 02, Center, South, Resistance:	12.486
3034	H02CS4	Heater, Zone 02, Center, South, Resistance:	12.481
3035	H02OS1	Heater, Zone 02, Outside, South, Resistance:	12.139
3036	H02OS2	Heater, Zone 02, Outside, South, Resistance:	12.474
3037	H02OS3	Heater, Zone 02, Outside, South, Resistance:	12.406
3038	H02OS4	Heater, Zone 02, Outside, South, Resistance:	12.494
3039	H02ES1	Heater, Zone 02, Edge, South, Resistance:	12.492
3040	H02ES2	Heater, Zone 02, Edge, South, Resistance:	11.889
3041	H03EN1	Heater, Zone 03, Edge, North, Resistance:	12.051
3042	H03EN2	Heater, Zone 03, Edge, North, Resistance:	12.293
3043	H03ON1	Heater, Zone 03, Outside, North, Resistance:	12.338
3044	H03ON2	Heater, Zone 03, Outside, North, Resistance:	12.132
3045	H03ON3	Heater, Zone 03, Outside, North, Resistance:	12.290
3046	H03ON4	Heater, Zone 03, Outside, North, Resistance:	11.960
3047	H03CN1	Heater, Zone 03, Center, North, Resistance:	12.251
3048	H03CN2	Heater, Zone 03, Center, North, Resistance:	12.024

Table 3-17. DAS Heater Element ID and Resistance List (cont'd)

PNUM	PID	PTITLE	ohms
3049	H03CN3	Heater, Zone 03, Center, North, Resistance:	11.992
3050	H03CN4	Heater, Zone 03, Center, North, Resistance:	12.137
3051	H03CS1	Heater, Zone 03, Center, South, Resistance:	12.047
3052	H03CS2	Heater, Zone 03, Center, South, Resistance:	12.174
3053	H03CS3	Heater, Zone 03, Center, South, Resistance:	12.502
3054	H03CS4	Heater, Zone 03, Center, South, Resistance:	11.973
3055	H03OS1	Heater, Zone 03, Outside, South, Resistance:	11.931
3056	H03OS2	Heater, Zone 03, Outside, South, Resistance:	12.371
3057	H03OS3	Heater, Zone 03, Outside, South, Resistance:	12.329
3058	H03OS4	Heater, Zone 03, Outside, South, Resistance:	12.163
3059	H03ES1	Heater, Zone 03, Edge, South, Resistance:	12.362
3060	H03ES2	Heater, Zone 03, Edge, South, Resistance:	12.510
3061	H04EN1	Heater, Zone 04, Edge, North, Resistance:	12.375
3062	H04EN2	Heater, Zone 04, Edge, North, Resistance:	12.163
3063	H04ON1	Heater, Zone 04, Outside, North, Resistance:	12.299
3064	H04ON2	Heater, Zone 04, Outside, North, Resistance:	12.466
3065	H04ON3	Heater, Zone 04, Outside, North, Resistance:	12.053
3066	H04ON4	Heater, Zone 04, Outside, North, Resistance:	12.033
3067	H04CN1	Heater, Zone 04, Center, North, Resistance:	11.934
3068	H04CN2	Heater, Zone 04, Center, North, Resistance:	12.446
3069	H04CN3	Heater, Zone 04, Center, North, Resistance:	12.364
3070	H04CN4	Heater, Zone 04, Center, North, Resistance:	12.368
3071	H04CS1	Heater, Zone 04, Center, South, Resistance:	12.448
3072	H04CS2	Heater, Zone 04, Center, South, Resistance:	12.326
3073	H04CS3	Heater, Zone 04, Center, South, Resistance:	12.434
3074	H04CS4	Heater, Zone 04, Center, South, Resistance:	12.321
3075	H04OS1	Heater, Zone 04, Outside, South, Resistance:	12.175
3076	H04OS2	Heater, Zone 04, Outside, South, Resistance:	12.421
3077	H04OS3	Heater, Zone 04, Outside, South, Resistance:	12.521
3078	H04OS4	Heater, Zone 04, Outside, South, Resistance:	12.377
3079	H04ES1	Heater, Zone 04, Edge, South, Resistance:	12.056
3080	H04ES2	Heater, Zone 04, Edge, South, Resistance:	12.279
3081	H05EN1	Heater, Zone 05, Edge, North, Resistance:	11.979
3082	H05EN2	Heater, Zone 05, Edge, North, Resistance:	11.970
3083	H05ON1	Heater, Zone 05, Outside, North, Resistance:	12.022
3084	H05ON2	Heater, Zone 05, Outside, North, Resistance:	12.318
3085	H05ON3	Heater, Zone 05, Outside, North, Resistance:	12.331
3086	H05ON4	Heater, Zone 05, Outside, North, Resistance:	12.117
3087	H05CN1	Heater, Zone 05, Center, North, Resistance:	12.834
3088	H05CN2	Heater, Zone 05, Center, North, Resistance:	12.408
3089	H05CN3	Heater, Zone 05, Center, North, Resistance:	12.066
3090	H05CN4	Heater, Zone 05, Center, North, Resistance:	12.289
3091	H05CS1	Heater, Zone 05, Center, South, Resistance:	12.311
3092	H05CS2	Heater, Zone 05, Center, South, Resistance:	12.353
3093	H05CS3	Heater, Zone 05, Center, South, Resistance:	12.343
3094	H05CS4	Heater, Zone 05, Center, South, Resistance:	12.363
3095	H05OS1	Heater, Zone 05, Outside, South, Resistance:	11.977
3096	H05OS2	Heater, Zone 05, Outside, South, Resistance:	12.374

Table 3-17. DAS Heater Element ID and Resistance List (cont'd)

PNUM	PID	PTITLE
3097	H05OS3	Heater, Zone 05, Outside, South, Resistance: 12.238
3098	H05OS4	Heater, Zone 05, Outside, South, Resistance: 12.145
3099	H05ES1	Heater, Zone 05, Edge, South, Resistance: 11.947
3100	H05ES2	Heater, Zone 05, Edge, South, Resistance: 11.848
3101	H06EN1	Heater, Zone 06, Edge, North, Resistance: 11.986
3102	H06EN2	Heater, Zone 06, Edge, North, Resistance: 12.557
3103	H06ON1	Heater, Zone 06, Outside, North, Resistance: 12.210
3104	H06ON2	Heater, Zone 06, Outside, North, Resistance: 12.384
3105	H06ON3	Heater, Zone 06, Outside, North, Resistance: 12.495
3106	H06ON4	Heater, Zone 06, Outside, North, Resistance: 11.940
3107	H06CN1	Heater, Zone 06, Center, North, Resistance: 12.129
3108	H06CN2	Heater, Zone 06, Center, North, Resistance: 12.355
3109	H06CN3	Heater, Zone 06, Center, North, Resistance: 12.504
3110	H06CN4	Heater, Zone 06, Center, North, Resistance: 12.204
3111	H06CS1	Heater, Zone 06, Center, South, Resistance: 11.970
3112	H06CS2	Heater, Zone 06, Center, South, Resistance: 12.386
3113	H06CS3	Heater, Zone 06, Center, South, Resistance: 12.357
3114	H06CS4	Heater, Zone 06, Center, South, Resistance: 12.108
3115	H06OS1	Heater, Zone 06, Outside, South, Resistance: 12.498
3116	H06OS2	Heater, Zone 06, Outside, South, Resistance: 12.085
3117	H06OS3	Heater, Zone 06, Outside, South, Resistance: 12.322
3118	H06OS4	Heater, Zone 06, Outside, South, Resistance: 12.568
3119	H06ES1	Heater, Zone 06, Edge, South, Resistance: 12.052
3120	H06ES2	Heater, Zone 06, Edge, South, Resistance: 12.084
3121	H07EN1	Heater, Zone 07, Edge, North, Resistance: 11.912
3122	H07EN2	Heater, Zone 07, Edge, North, Resistance: 12.317
3123	H07ON1	Heater, Zone 07, Outside, North, Resistance: 12.353
3124	H07ON2	Heater, Zone 07, Outside, North, Resistance: 12.140
3125	H07ON3	Heater, Zone 07, Outside, North, Resistance: 11.990
3126	H07ON4	Heater, Zone 07, Outside, North, Resistance: 11.981
3127	H07CN1	Heater, Zone 07, Center, North, Resistance: 12.389
3128	H07CN2	Heater, Zone 07, Center, North, Resistance: 12.025
3129	H07CN3	Heater, Zone 07, Center, North, Resistance: 12.086
3130	H07CN4	Heater, Zone 07, Center, North, Resistance: 12.118
3131	H07CS1	Heater, Zone 07, Center, South, Resistance: 12.752
3132	H07CS2	Heater, Zone 07, Center, South, Resistance: 11.981
3133	H07CS3	Heater, Zone 07, Center, South, Resistance: 12.320
3134	H07CS4	Heater, Zone 07, Center, South, Resistance: 11.817
3135	H07OS1	Heater, Zone 07, Outside, South, Resistance: 12.484
3136	H07OS2	Heater, Zone 07, Outside, South, Resistance: 12.114
3137	H07OS3	Heater, Zone 07, Outside, South, Resistance: 12.086
3138	H07OS4	Heater, Zone 07, Outside, South, Resistance: 12.031
3139	H07ES1	Heater, Zone 07, Edge, South, Resistance: 11.873
3140	H07ES2	Heater, Zone 07, Edge, South, Resistance: 12.194
3141	H08EN1	Heater, Zone 08, Edge, North, Resistance: 12.235
3142	H08EN2	Heater, Zone 08, Edge, North, Resistance: 12.024
3143	H08ON1	Heater, Zone 08, Outside, North, Resistance: 11.797
3144	H08ON2	Heater, Zone 08, Outside, North, Resistance: 11.779

Table 3-17. DAS Heater Element ID and Resistance List (cont'd)

PNUM	PID	PTITLE
3145	H08ON3	Heater, Zone 08, Outside, North, Resistance: 11.952
3146	H08ON4	Heater, Zone 08, Outside, North, Resistance: 11.926
3147	H08CN1	Heater, Zone 08, Center, North, Resistance: 11.762
3148	H08CN2	Heater, Zone 08, Center, North, Resistance: 12.063
3149	H08CN3	Heater, Zone 08, Center, North, Resistance: 11.905
3150	H08CN4	Heater, Zone 08, Center, North, Resistance: 12.193
3151	H08CS1	Heater, Zone 08, Center, South, Resistance: 11.934
3152	H08CS2	Heater, Zone 08, Center, South, Resistance: 11.807
3153	H08CS3	Heater, Zone 08, Center, South, Resistance: 11.866
3154	H08CS4	Heater, Zone 08, Center, South, Resistance: 11.911
3155	H08OS1	Heater, Zone 08, Outside, South, Resistance: 12.141
3156	H08OS2	Heater, Zone 08, Outside, South, Resistance: 11.785
3157	H08OS3	Heater, Zone 08, Outside, South, Resistance: 11.885
3158	H08OS4	Heater, Zone 08, Outside, South, Resistance: 11.822
3159	H08ES1	Heater, Zone 08, Edge, South, Resistance: 11.960
3160	H08ES2	Heater, Zone 08, Edge, South, Resistance: 12.533
3161	H09EN1	Heater, Zone 09, Edge, North, Resistance: 11.959
3162	H09EN2	Heater, Zone 09, Edge, North, Resistance: 12.083
3163	H09ON1	Heater, Zone 09, Outside, North, Resistance: 12.405
3164	H09ON2	Heater, Zone 09, Outside, North, Resistance: 12.189
3165	H09ON3	Heater, Zone 09, Outside, North, Resistance: 12.360
3166	H09ON4	Heater, Zone 09, Outside, North, Resistance: 11.925
3167	H09CN1	Heater, Zone 09, Center, North, Resistance: 12.140
3168	H09CN2	Heater, Zone 09, Center, North, Resistance: 12.434
3169	H09CN3	Heater, Zone 09, Center, North, Resistance: 11.954
3170	H09CN4	Heater, Zone 09, Center, North, Resistance: 12.196
3171	H09CS1	Heater, Zone 09, Center, South, Resistance: 11.975
3172	H09CS2	Heater, Zone 09, Center, South, Resistance: 12.086
3173	H09CS3	Heater, Zone 09, Center, South, Resistance: 11.993
3174	H09CS4	Heater, Zone 09, Center, South, Resistance: 12.271
3175	H09OS1	Heater, Zone 09, Outside, South, Resistance: 11.890
3176	H09OS2	Heater, Zone 09, Outside, South, Resistance: 12.216
3177	H09OS3	Heater, Zone 09, Outside, South, Resistance: 11.840
3178	H09OS4	Heater, Zone 09, Outside, South, Resistance: 12.382
3179	H09ES1	Heater, Zone 09, Edge, South, Resistance: 12.248
3180	H09ES2	Heater, Zone 09, Edge, South, Resistance: 12.096
3181	H10EN1	Heater, Zone 10, Edge, North, Resistance: 12.034
3182	H10EN2	Heater, Zone 10, Edge, North, Resistance: 11.865
3183	H10ON1	Heater, Zone 10, Outside, North, Resistance: 12.492
3184	H10ON2	Heater, Zone 10, Outside, North, Resistance: 12.543
3185	H10ON3	Heater, Zone 10, Outside, North, Resistance: 12.216
3186	H10ON4	Heater, Zone 10, Outside, North, Resistance: 12.255
3187	H10CN1	Heater, Zone 10, Center, North, Resistance: 12.496
3188	H10CN2	Heater, Zone 10, Center, North, Resistance: 11.843
3189	H10CN3	Heater, Zone 10, Center, North, Resistance: 12.291
3190	H10CN4	Heater, Zone 10, Center, North, Resistance: 12.017
3191	H10CS1	Heater, Zone 10, Center, South, Resistance: 12.451
3192	H10CS2	Heater, Zone 10, Center, South, Resistance: 12.542
3193	H10CS3	Heater, Zone 10, Center, South, Resistance: 12.066
3194	H10CS4	Heater, Zone 10, Center, South, Resistance: 12.158
3195	H10OS1	Heater, Zone 10, Outside, South, Resistance: 11.909
3196	H10OS2	Heater, Zone 10, Outside, South, Resistance: 12.497
3197	H10OS3	Heater, Zone 10, Outside, South, Resistance: 12.346
3198	H10OS4	Heater, Zone 10, Outside, South, Resistance: 12.032
3199	H10ES1	Heater, Zone 10, Edge, South, Resistance: 12.391
3200	H10ES2	Heater, Zone 10, Edge, South, Resistance: 11.905

Table 3-18. DAS Series and Parallel Heater String ID and Resistance List

PNUM	PID	PTITLE
3401	SH01C1	Series Heater, Zone 01, Center, Resistance: 48.257
3402	SH01C2	Series Heater, Zone 01, Center, Resistance: 48.441
3403	SH01C3	Series Heater, Zone 01, Center, Resistance: 48.035
3404	SH01C4	Series Heater, Zone 01, Center, Resistance: 49.140
3405	SH01EN	Series Heater, Zone 01, Edge North, Resistance: 24.288
3406	SH01ES	Series Heater, Zone 01, Edge South, Resistance: 24.042
3407	PH01C	Parallel Heater, Zone 01, Center, Resistance: 12.63
3408	SH01E	Series Heater, Zone 01 Edge (Both Sides), Resistance: 50.52
3409	SH02C1	Series Heater, Zone 02, Center, Resistance: 49.405
3410	SH02C2	Series Heater, Zone 02, Center, Resistance: 49.157
3411	SH02C3	Series Heater, Zone 02, Center, Resistance: 49.673
3412	SH02C4	Series Heater, Zone 02, Center, Resistance: 49.434
3413	SH02EN	Series Heater, Zone 02, Edge North, Resistance: 24.905
3414	SH02ES	Series Heater, Zone 02, Edge South, Resistance: 24.381
3415	PH02C	Parallel Heater, Zone 02, Center, Resistance: 12.883
3416	SH02E	Series Heater, Zone 02 Edge (Both Sides), Resistance: 51.28
3417	SH03C1	Series Heater, Zone 03, Center, Resistance: 48.567
3418	SH03C2	Series Heater, Zone 03, Center, Resistance: 48.701
3419	SH03C3	Series Heater, Zone 03, Center, Resistance: 49.113
3420	SH03C4	Series Heater, Zone 03, Center, Resistance: 48.233
3421	SH03EN	Series Heater, Zone 03, Edge North, Resistance: 24.344
3422	SH03ES	Series Heater, Zone 03, Edge South, Resistance: 24.872
3423	PH03C	Parallel Heater, Zone 03, Center, Resistance: 12.68
3424	SH03E	Series Heater, Zone 03 Edge (Both Sides), Resistance: 51.15
3425	SH04C1	Series Heater, Zone 04, Center, Resistance: 48.856
3426	SH04C2	Series Heater, Zone 04, Center, Resistance: 49.659
3427	SH04C3	Series Heater, Zone 04, Center, Resistance: 49.372
3428	SH04C4	Series Heater, Zone 04, Center, Resistance: 49.099
3429	SH04EN	Series Heater, Zone 04, Edge North, Resistance: 24.538
3430	SH04ES	Series Heater, Zone 04, Edge South, Resistance: 24.335
3431	PH04C	Parallel Heater, Zone 04, Center, Resistance: 12.83
3432	SH04E	Series Heater, Zone 04 Edge (Both Sides), Resistance: 50.85
3433	SH05C1	Series Heater, Zone 05, Center, Resistance: 48.144
3434	SH05C2	Series Heater, Zone 05, Center, Resistance: 49.453
3435	SH05C3	Series Heater, Zone 05, Center, Resistance: 48.978
3436	SH05C4	Series Heater, Zone 05, Center, Resistance: 48.914
3437	SH05EN	Series Heater, Zone 05, Edge North, Resistance: 23.9[illegible]9
3438	SH05ES	Series Heater, Zone 05, Edge South, Resistance: 23.795
3439	PH05C	Parallel Heater, Zone 05, Center, Resistance: 12.734
3440	SH05E	Series Heater, Zone 05 Edge (Both Sides), Resistance: 49.68

Table 3-18. DAS Series and Parallel Heater String ID and Resistance List (cont'd)

PNUM	PID	PTITLE
3441	SH06C1	Series Heater, Zone 06, Center, Resistance: 48.815
3442	SH06C2	Series Heater, Zone 06, Center, Resistance: 49.210
3443	SH06C3	Series Heater, Zone 06, Center, Resistance: 49.678
3444	SH06C4	Series Heater, Zone 06, Center, Resistance: 48.820
3445	SH06EN	Series Heater, Zone 06, Edge North, Resistance: 24.543
3446	SH06ES	Series Heater, Zone 06, Edge South, Resistance: 24.136
3447	PH06C	Parallel Heater, Zone 06, Center, Resistance: 12.779
3448	SH06E	Series Heater, Zone 06 Edge (Both Sides), Resistance: 50.52
3449	SH07C1	Series Heater, Zone 07, Center, Resistance: 48.978
3450	SH07C2	Series Heater, Zone 07, Center, Resistance: 48.260
3451	SH07C3	Series Heater, Zone 07, Center, Resistance: 48.482
3452	SH07C4	Series Heater, Zone 07, Center, Resistance: 48.047
3453	SH07EN	Series Heater, Zone 07, Edge North, Resistance: 24.229
3454	SH07ES	Series Heater, Zone 07, Edge South, Resistance: 24.067
3455	PH07C	Parallel Heater, Zone 07, Center, Resistance: 12.626
3456	SH07E	Series Heater, Zone 07 Edge (Both Sides), Resistance: 50.23
3457	SH08C1	Series Heater, Zone 08, Center, Resistance: 47.634
3458	SH08C2	Series Heater, Zone 08, Center, Resistance: 47.434
3459	SH08C3	Series Heater, Zone 08, Center, Resistance: 47.608
3460	SH08C4	Series Heater, Zone 08, Center, Resistance: 47.852
3461	SH08EN	Series Heater, Zone 08, Edge North, Resistance: 24.259
3462	SH08ES	Series Heater, Zone 08, Edge South, Resistance: 24.293
3463	PH08C	Parallel Heater, Zone 08, Center, Resistance: 12.41
3464	SH08E	Series Heater, Zone 08 Edge (Both Sides), Resistance: 50.59
3465	SH09C1	Series Heater, Zone 09, Center, Resistance: 48.410
3466	SH09C2	Series Heater, Zone 09, Center, Resistance: 49.927
3467	SH09C3	Series Heater, Zone 09, Center, Resistance: 48.147
3468	SH09C4	Series Heater, Zone 09, Center, Resistance: 48.774
3469	SH09EN	Series Heater, Zone 09, Edge North, Resistance: 24.042
3470	SH09ES	Series Heater, Zone 09, Edge South, Resistance: 24.346
3471	PH09C	Parallel Heater, Zone 09, Center, Resistance: 12.66
3472	SH09E	Series Heater, Zone 09 Edge (Both Sides), Resistance: 50.23
3473	SH10C1	Series Heater, Zone 10, Center, Resistance: 49.348
3474	SH10C2	Series Heater, Zone 10, Center, Resistance: 49.245
3475	SH10C3	Series Heater, Zone 10, Center, Resistance: 48.919
3476	SH10C4	Series Heater, Zone 10, Center, Resistance: 48.485
3477	SH10EN	Series Heater, Zone 10, Edge North, Resistance: 23.899
3478	SH10ES	Series Heater, Zone 10, Edge South, Resistance: 24.296
3479	PH10C	Parallel Heater, Zone 10, Center, Resistance: 12.76
3480	SH10E	Series Heater, Zone 10 Edge (Both Sides), Resistance: 50.01

4.0 TEST OPERATIONS

From the available design descriptions for the PRISM and SAFR concepts, it appears that the Air-Side Full-Scale Tests performed at ANL should encompass a range of heat fluxes, flow resistances and weather conditions that could exist following an inherent reactor shutdown wherein decay heat removal is entirely dependent upon the passive free convection effects of air flow between the reactor guard vessel (G.V.) and the surrounding duct wall. The initial (Phase I) test plan for the no-fin case is predicated on the following general conditions and strategy:

A. Thermal

1. Uniform G.V. wall temperature distribution to a maximum of 900°F (482°C).

2. Uniform G.V. heat flux to 2 Kw/ft^2 (~20 Kw/m^2).

3. Stepwise variable heat flux in the axial direction to simulate possible stratification of sodium temperatures in the reactor vessel.

4. Prototypic wall emissivities.

B. Fluid Dynamics

1. Very low flow resistance (standard test loss coefficient, $K \cong 1.5$) to a loss coefficient of approximately twenty ($K = 20$) (referenced to the heated section cross-sectional area).

2. Flow channel dimensions will simulate a portion of the G.V. and duct wall design such that the air velocity profiles are prototypic.

C. It has been speculated that weather (particularly wind) conditions may affect the RVACS/RACS performance. Initially, the tests will be performed with the weather cap in place. Outside and inside ambient conditions will be monitored during testing and possible effects will be investigated. Selected test runs will be duplicated with the weather cap removed or replaced with low loss weather cap.

D. The test matrix as proposed at the ANL/GE meeting of 2/19/86 contains a large number of possible parametric sets for data collection. In addition, the possible number and location of air flow measurements (pressure and temperature) is large. This initial (Phase I) plan proposes to collect data at selected matrix points in relatively large parameter increments and a small number of pitot tube and thermocouple traverses to minimize experiment durations and data acquisition storage requirements. The results of Phase I operation will determine the required extent of the test matrix for Phase II.

E. The Phase I test matrix and possible Phase II (extended) test descriptions are presented in Table 4-1 below, and a summary of the planned convection tests based on predicted performance parameters is given in Table 4-2.

5.0 DATA ANALYSIS

5.1 RVACS Performance Parameters

The primary goal of the RVACS experiment is to provide passive heat removal performance data characteristic of the full-scale RVACS design. The test assembly provides a prototypic simulation of a vertical section of the guard vessel wall (heated wall) and the surrounding collector wall (duct wall). Pretest calculations and parametric studies have provided the predicted performance curves shown in Figures 5-1, 5-2 and 5-3. Verification of these analytical results will provide useful support of the primary experiment goal.

Part of the test operations strategy is based upon these analytical curves, i.e., the parametric values selected for test operations should fully

Table 4.1 RVACS TEST PLAN MATRIX

Time Required (8 hrs/day) (Days)		Comments
	4.1 Initial System Checkout and Characterization	
5	4.1.1 Zero Flow, Zero Power - Simulate test run data acquisition and on-line processing for a "steady-state" condtion.	Checkout for all Instrumentation and DAS systems.
3	4.1.2 Zero Power, Forced Convection for range of Re = 0.3 to 2×10^5 ($V \simeq 3$ to 20 ft/sec).	Characterize flow profiles.
	• check for system leakage.	
	• Measure velocity profiles at six axial locations and 5-8 lateral positions.	
	• Record and process all system variables for "small" time increments correlated to traverse positions.	
11	4.1.3 Power on, Forced Convection	Verify heater operations and control modes, bakeout heaters, charcterize forced convection operation as basis for subsequent data analysis.
	• Set fan to $V \cong 15$ ft/sec ($Re = 1.5 \times 10^5$)	
	• Heater Tests and Bakeout (constant temperature	
	• Zoned Power Tests.	
	• Stepwise heater operation for electrical integrity, one zone at a time, control mode -- constant temperature at 250°F, 600°F, 900°F. Heater temp less than 1600°F.	Note the increase in radiative heat flux ($\sim T^4$) to collector wall as function of temperature T(F) — $T^4 (R^4)$ 250 — 2.5×10^{11} 600 — 1.3×10^{12} 900 — 3.4×10^{12}
	• Record and process all system variables for "short" time increments, including velocity profiles.	

Table 4.1 RVACS TEST PLAN MATRIX (contd.)

Time Required (8 hrs/day) (Days)		Comments
	• All-Zone Power Tests	
	• Stepwise heater operation, all zones on, "equilibrium" tests for constant temperature control mode at 250°F, 600°F, 900°F periodically.	
	• Record and process selected variables for approach to steady state (will be relatively long-term since this is the bakeout phase).	
	• Record and process all system variables at three stages.	Heat flux and heat loss validation.
	• Heater Tests (constant heat flux control mode).	This activity is subject to the time limitations for part A (11 days) i.e., these tests may be deferred to Phase II).
	• Repeat all-zone power tests at 0.5, 1.0, and 1.5 Kw/ft^2 (5, 10, and 15 Kw/m^2).	
	• Repeat all-zone power tests for stepwise power increments by "zones (no. is TBD).	
15	4.2 Convection Tests	
	4.2.1 All-zone constant temperature control mode at 250°F, 600°F, and 900°F. (see Table 4.2 for matrix)	Acquisition of basic data for performance evaluation of the RVACS no-fin design.
	• Vary loss coefficient K from min. (~1.5) to max. (~20) for each each temperature setting. The tests will encompass a Re range from 0.25 to 1.5 x 10^5 by a combination of free and forced convection tests. Each temperature setting will be characterized by at least five sets of data within the target flow range.	For free convection at $K \simeq 1.5$ pretest calculations indicate that T_{GV} (°F) — Re — Avg. Q_w (Kw/m^2) 280 — 0.75×10^5 — 1.1 600 — 1.2×10^5 — 5.5 900 — 1.5×10^5 — 11.0

Table 4.1 RVACS TEST PLAN MATRIX (contd.)

Time Required (8 hrs/day) (Days)		Comments
	• Forced flow for Re ⩾ 1.0×10^5 for 250°F and 600°F tests.	
	4.2.2 All-zone constant heat flux control mode at 0.5, 1.0, and 1.5 Kw/ft^2 (5, 10, and 15 Kw/m^2), varying K as in 4.2.1.	*This activity is subject to the time limitation of part B (i.e. these may be deferred to Phase II).
	4.2.3 Totally close inlet and all port holes for short time interval for one test at 900°F.	
	4.2.4 Perform a "Long Term" operation, ~5 days.	
	4.2.5 Zoned constant temperature control mode (stratification simulation) at 400°F, 600°F, 800°F.*	
	4.3 Possible Additional Tests - Phase II	
	4.3.1 During all of the tests above, the outside weather conditions will be monitored (particularly wind velocity and direction). If it appears that experiment data anomalies are related to changing meteorological conditions, procedures will be devised to account for these effects, perhaps by rerunning selected tests during selected meteorological conditions and/or utilizing alternate stack exit design.	
	4.3.2 It is possible that more detailed experiment data will be required for precision in computing performance data, e.g., intermediate values of temperature, heat flux and pressure loss settings.	
	4.3.3 Repeatability Tests, additional combined forced convection, free convection effects.	

Table 4.2 RVACS Experiment Matrix-Predicted Performance Parameters (Approximate Parameter Setpoints).

K / Re / Temp °F	Free Convection			Forced Convection	
250	24 0.25×10^5 *	4.5 0.5×10^5	1.5 0.75×10^5 *	-- 1.0×10^5	-- 1.5×10^5 *
600	NA	16 0.5×10^5	6 0.75×10^5	3.5 1.0×10^5	-- 1.5×10^5
900	NA	NA	9.5 0.75×10^5 *	4.5 1.0×10^5	1.5 1.5×10^5 *

*At these setpoints velocity and temperature traverses will be obtained.

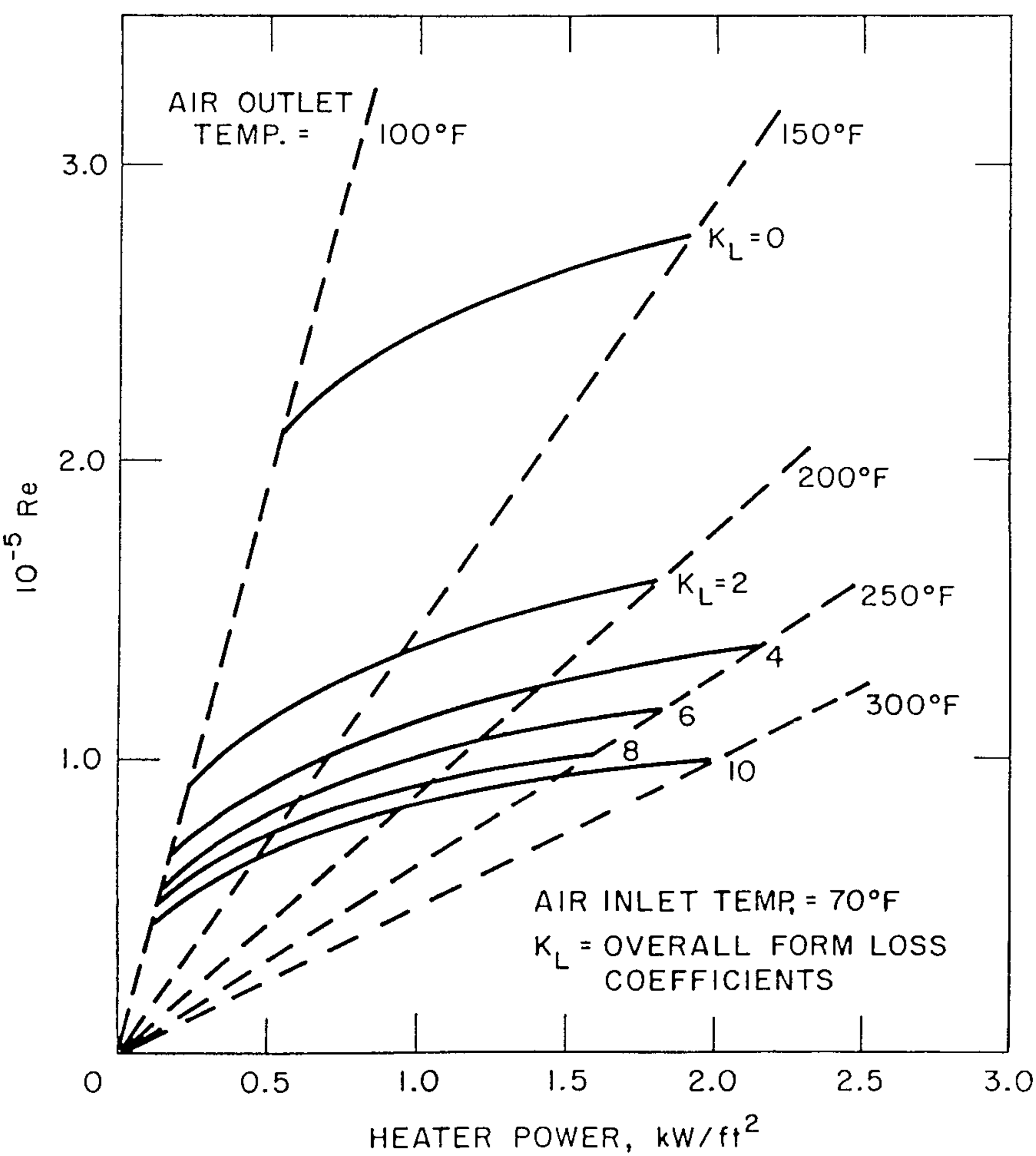


Figure 5-1. Test Assembly Performance Map

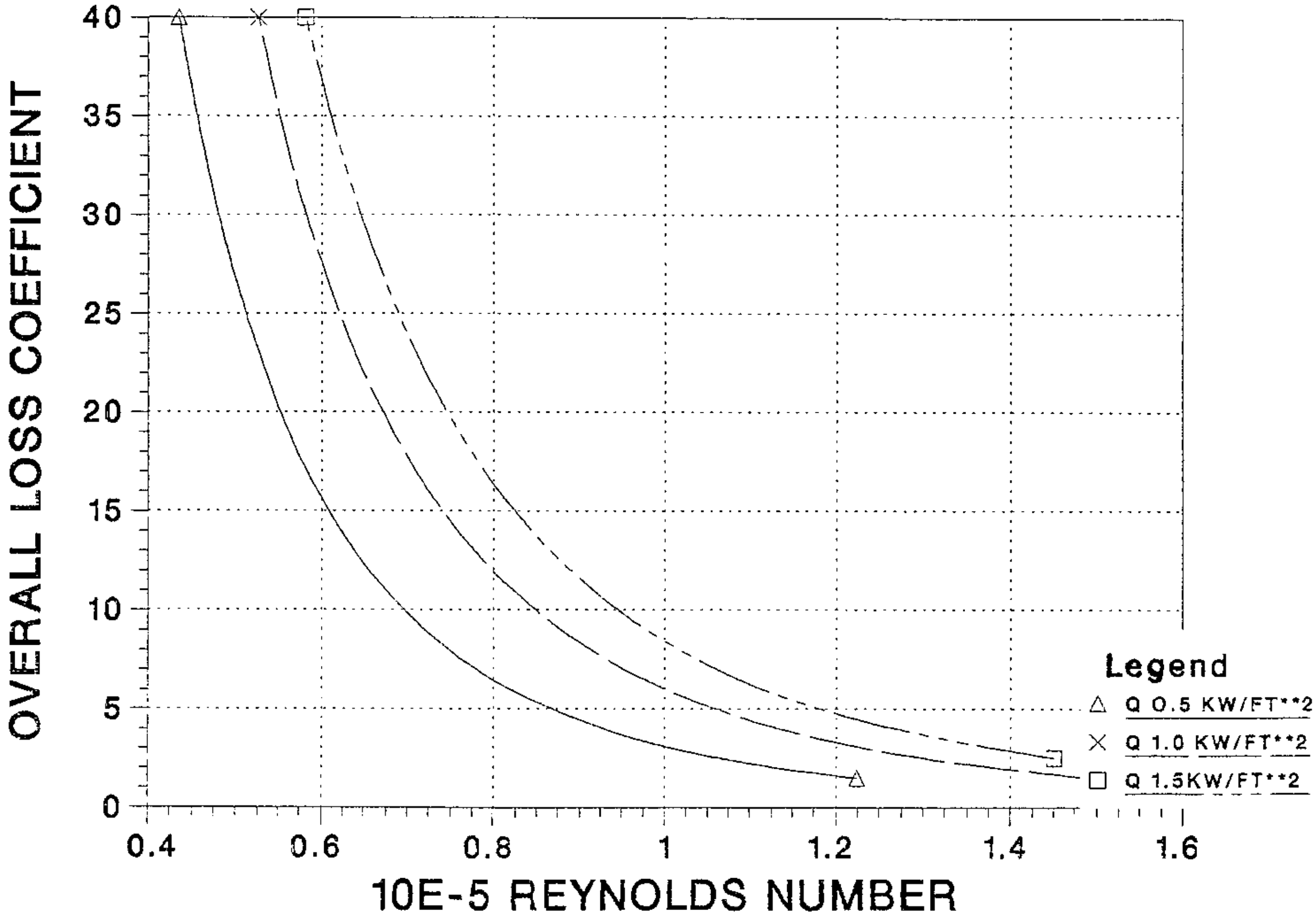


Figure 5-2. RVACS Performance for Various Values of Applied Heat Flux.

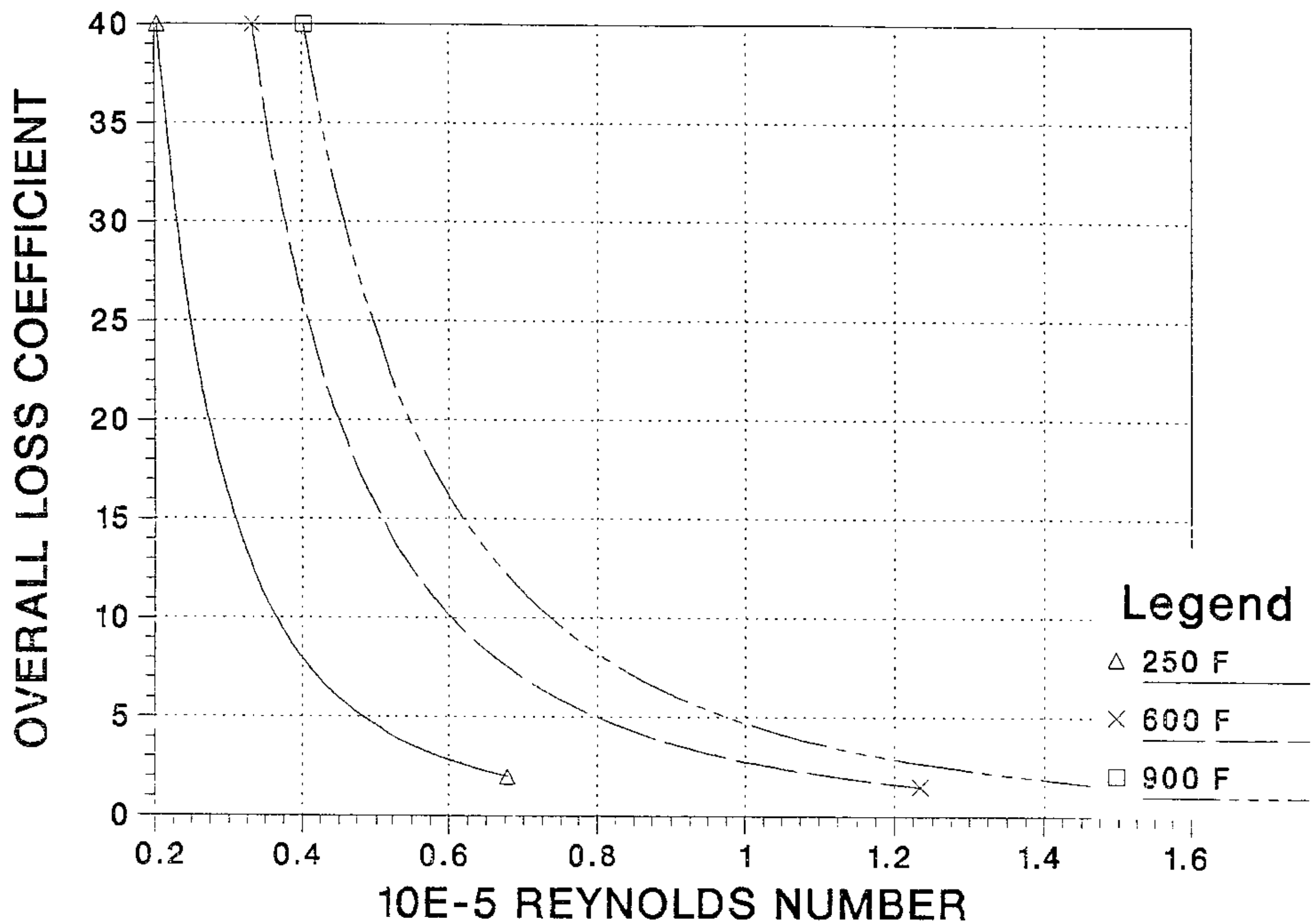


Figure 5-3. RVACS Performance for Various Guard Vessel Temperatures.

characterize these curves. As indicated by perusal of these pretest results, the following ranges of the primary parameters have been selected for Phase I operations:

Temperature set points: 250°F, 600°F, and 900°F
System Losses: K = 1.5 to 20 (expressed as no. of velocity heads at test section inlet)
Power per unit area set points: 0.5, 1.0, and 1.5 Kw/ft^2
Inlet Reynolds Number: 0.25×10^5 to 1.5×10^5

Following the initial checkout and bakeout operations, the Phase I operations are run in two main modes: (a) constant power (uniform heat flux) and (b) constant guard vessel surface temperature (because of the 10-zone incremental power control, this is actually a smoothed saw-toothed wave).

5.1.1 Constant Heat Flux Operation

In this mode, all ten heater zones are set to provide uniform heat flux to the heated wall for one system loss configuration. At equilibrium the following relationships apply to the calculation of RVACS performance:

At any elevation, the guard vessel heat flux is

$$q''(x) = h_t(x)\,[T_{GV}(x) - T_a(x)], \qquad (1)$$

where

$q''(x)$ = heat flux from GV wall, $B/hr\text{-}ft^2$;

h_t = total heat transfer coefficient, $B/hr\text{-}ft^2\text{-}°F$;

$T_{GV}(x)$ = local GV air-side surface temperature, °F;

$T_a(x)$ = local bulk air temperature, °F.

Also,

$$q''(x) = \left(\frac{1}{A_{GV}}\right) \dot{m}\, c_p\, (T_2 - T_1), \tag{2}$$

where

A_{GV} = total guard vessel heat transfer area, ft^2;

$\dot{m}$ = air mass flow rate, lb/hr;

c_p = specific heat of air, B/lb-°F;

T_1 = Heated section inlet air temperature, °F;

T_2 = heated section outlet air temperature, °F.

Also,

$$\dot{m} = \rho\, A_R V, \tag{3}$$

where

ρ = outlet air density, lb/ft^3;

A_R = Cross-sectional flow area at rake (VOLU-probe) elevation, ft^2;

V = Air velocity as measured by flow rake, ft/hr.

5.1.1.1 Calculation of Wall and Air Temperatures

The locations of the heated wall and duct wall thermocouples are indicated in Figs. 3-20 thru 3-24. As shown there are thirty-one (31) discrete TC elevations which can be used for calculations. Although there are a number of alternatives with respect to location, number of calculations, and methods of averaging TC readings, the initial selection will use the center two TCs on each wall as follows:

Elevation, x_i (inches from reference zero)	No. of TCs Averaged Heated Wall	Duct Wall
x_1 = 5"	2	2
x_2 = 31"	2	2
x_3 = 57"	2	2
x_4 = 83"	2	2
x_5 = 109"	2	2
(For power calculations subtract 9" from each of x_6 through h x_{10})		
x_6 = 146"	2	2
x_7 = 172"	2	2
x_8 = 198"	2	2
x_9 = 224"	2	2
x_{10} = 250"	2	2

Wall Temperatures

$$T_{GV}(x_i) = \frac{T_{1i} + T_{2i}}{2} \tag{4}$$

$$T_{DW}(x_i) = \frac{T_{3i} + T_{4i}}{2} \tag{5}$$

Air Temperatures

The local air temperatures are calculated assuming air temperature increase is linear with heated section length:

$$T_a(x_i) = T_1 + \frac{x_i}{L}(T_2 - T_1) \tag{8}$$

where L = total heated length, in.

5.1.1.2 Heat Transfer Coefficients

The total heat transfer coefficienct, h_t, at the GV wall is:

$$h_t(x) = \frac{q''(x)}{T_{GV}(x) - T_a(x)}. \tag{9}$$

since

$$q''(x) = q''_c(x) + q''_r(x), \tag{10}$$

where the subscripts c and r represent convection and radiation respectively, and

$$q''_{DW}(x) = q''_r(x), \tag{11}$$

where DW = duct wall, the convective and radiative heat transfer coefficients can be calculated by

$$h_{GV_c} = \frac{q''_c(x)}{T_{GV}(x) - T_a(x)}, \tag{12}$$

$$h_{GV_r} = \frac{q''_{DW}(x)}{T_{DW}(x) - T_a(x)} = h_{DW_c}. \tag{14}$$

Although there are many experimental correlations for free convection coefficients, a number of them are expressed as

$$h = C(\Delta T)^b, \tag{15}$$

where

b, C = constants

and $\Delta T = T_{wall} - T_{fluid}$ (16)

Assuming that this power law is valid for the RVACS simulation and that the constant C is the same for both walls at one elevation,

$$\frac{h_{GV_c}}{h_{DW_c}} = \left(\frac{\Delta T_{GV}}{\Delta T_{DW}}\right)^b , \tag{17}$$

where b = 1/3 for turbulent free convection air flow over vertical plates encompassing the temperature ranges encountered in this experiment.[46,47]

$$\text{Since } q''_c = h_{GV_c} \; (\Delta T_{GV}) \tag{18}$$

$$\text{and } q''_{DW} = h_{DW_c} \; (\Delta T_{DW}), \tag{19}$$

the ratio of the convective wall heat fluxes is

$$\frac{q''_c \;(x)}{q''_{DW} \;(x)} = \frac{h_{GV_c}}{h_{DW_c}} \frac{\Delta T_{GV}}{\Delta T_{DW}} = \left(\frac{\Delta T_{GV}}{\Delta T_{DW}}\right)^{1/3} \frac{\Delta T_{GV}}{\Delta T_{DW}} = \left(\frac{\Delta T_{GV}}{\Delta T_{DW}}\right)^{4/3} \tag{20}$$

and

$$q''_c \;(x) = q''_{DW} \;(x) \left(\frac{\Delta T_{GV}}{\Delta T_{DW}}\right)^{4/3} \tag{21}$$

Since

$$q'' \;(x) = q''_c \;(x) + q''_{DW} \;(x), \tag{22}$$

then

$$q'' \;(x) = q''_{DW} \;(x) \left[1 + \left(\frac{\Delta T_{GV}}{\Delta T_{DW}}\right)^{4/3}\right] \tag{23}$$

Since $q''\;(x)$, ΔT_{GV}, and ΔT_{DW} are measured quantities,

$$q''_{DW}(x) = q''_r(x) = \frac{q''(x)}{1 + \left[\frac{T_{GV}(x) - T_a(x)}{T_{DW}(x) - t_a(x)}\right]^{4/3}} \tag{24}$$

and

$$q''_c(x) = q''(x) - q''_{DW}(x). \tag{25}$$

Therefore all four coefficients can be calculated from the experimental data and can be displayed as a function of heated test section length.

5.1.1.3 Calculation of Reynolds Number

As with the system loss coefficients, the Reynolds Number, Re, will be referenced to test section inlet conditions as

$$Re = \frac{VD\rho}{\mu}, \tag{26}$$

where

$$V = \frac{\rho R}{\rho} \frac{A_R}{A_T} V_R . \tag{26a}$$

V_R is calculated from the rake ΔP at the rake temperature (used for ρR) and

ρ = density at inlet temperature, lb/ft^3

μ = viscosity at inlet temperature, lb/ft-hr

and D is the test section hydraulic diameter,

$$D = \frac{4\ A_T}{P_w}, \text{ ft}, \tag{27}$$

where

A_T = test section flow area, ft^2 and

P_w = test section wetted perimeter, ft.

It should be noted that the inlet Reynolds number is adequate to describe the system performance of the current design and will be presented as in Figures 5-2 and 5-3. However, for general correlation purposes (i.e., design correlations), the Reynolds numbers will be calculated using "average" properties and standard correlation techniques.

5.1.1.4 <u>On-Line Computations and Display Parameters</u>

For each test run to equilibrium, the following parameter values are displayed:

1. Barometric pressure, in Hg, wind direction and velocity
2. Inlet Air Temperature, °F
3. Test Section (TS) Outlet Temperature, °F
4. Inlet Reynolds Number
5. System Loss, K, referenced to TS inlet
6. Heated Wall (GV) power, KW/ft^2
7.* Total Heat Transfer Coefficient, h_t vs Heated Length, B/hr-ft^2-°F
8.* Heated Wall (GV) Convective Heat Transfer Coefficient, h_{GV_c}, vs Heated Length, B/hr-ft^2-°F
9.* Duct Wall Convective Heat Transfer Coefficient, h_{DW_c}, B/hr-ft^2-°F
10.* Radiative Heat Transfer Coefficient, h_r, B/hr-ft^2-°F

5.1.1.5 <u>Constants for On-Line Algorithms</u>

A_{GV} = 95.33 ft^2
c_p = 0.24 B/lb - °F
A_R = 6.50 ft^2
L = 22.0 ft = 264 in

---

* These values are calculated and plotted for the ten axial locations listed in 5.1.1.1.

The T_{1i}, T_{2i}, T_{3i}, and T_{4i} values are calculated from the following TC measurements at corresponding X_i locations (see sections 4 and 5.1.1.1)

x_1 : T_{11} = PNUM = 1001
T_{21} = PNUM = 1002
T_{31} = PNUM - 1016
T_{41} = PNUM = 1017

x_2 : T_{12} = PNUM = 1101
T_{22} = PNUM = 1102
T_{32} = PNUM = 1116
T_{42} = PNUM = 1117

x_3 : T_{13} = PNUM = 1201
T_{23} = PNUM = 1202
T_{33} = PNUM = 1216
T_{43} = PNUM = 1217

x_4 : T_{14} = PNUM = 1301
T_{24} = PNUM = 1302
T_{34} = PNUM = 1314
T_{44} = PNUM = 1315

x_5 : T_{15} = PNUM = 1401
T_{25} = PNUM = 1402
T_{35} = PNUM = 1416
T_{45} = PNUM = 1417

x_6 : T_{16} = PNUM = 1504
T_{26} = PNUM = 1505
T_{36} = PNUM = 1517
T_{46} = PNUM = 1518

x_7 : T_{17} = PNUM = 1601
T_{27} = PNUM = 1603
T_{37} = PNUM = 1610
T_{47} = PNUM = 1611

x_8 : T_{18} = PNUM = 1702
T_{28} = PNUM = 1703
T_{38} = PNUM = 1713
T_{48} = PNUM = 1714

x_9 : T_{19} = PNUM = 1801
T_{29} = PNUM = 1803
T_{39} = PNUM = 1810
T_{49} = PNUM = 1811

x_{10} : T_{10} = PNUM = 1901
T_{20} = PNUM = 1902
T_{30} = PNUM = 1912
T_{40} = PNUM = 1913

$A_T = 4.33 \text{ ft}^2$

$P_w = 10.67 \text{ ft}$

$D = 1.625 \text{ ft}$

$\mu = 0.03964 + 6.318 \times 10^{-5}\, T - 1.471 \times 10^{-8}\, T^2$

$\rho = (39.663) \left(\frac{1}{T_2 + 459.7}\right) \left(\frac{H}{760}\right)$,

where

H = local barometric pressure, mm Hg

5.1.2 Constant Temperature Operation

In the constant temperature mode, each of the ten separately controlled heater zones is maintained at the same "average" temperature. In general, the data reduction analysis of section 5.1.1 is applicable, with the exceptions of the local heat flux and local air temperature. For this mode, heat transfer coefficients are calculated from:

$$h\,(x_i) = \frac{q''\ (x_i)}{T_{GV_i} - T_{a_i}} = \frac{P_i/9.533}{T_{GV_i} - T_{a_i}}, \tag{28}$$

where P_i = Power into ith zone, B/hr-ft^2. For Phase I tests, T_{GV_i} is 250°F, 600°F, or 900°F and the thermocouples at x_i are selected as the control element for the ith zone.

The local air temperature is calculated as:

$$T_{a_i} = T_1 + \frac{\sum_{j=1}^{n} P_i}{\sum_{j=1}^{10} P_i} + \frac{5}{26} P_i\ (T_2 - T_1) \tag{29}$$

where

n = i-1

P_i = measured electrical power into the ith zone, KW

$= (\frac{E^2}{R_i})$ (SCR on-time)

where

E = average line voltage, V,

R_i = calibrated zone resistance, ohms,

and SCR on-time = time-averaged unidriver reading around thermal equilibrium, %/100.

5.1.2.1 On-Line Computations and Display Parameters

For each equilibrium run, the parameters listed in section 5.1.1.4 are displayed with the exception of item 6 which is changed to "Guard Vessel Wall Temperature".

All other calculations are carried out as in section 5.1.1. Heat transfer coefficients vs. heated length are similarly displayed.

5.1.3 RVACS System Performance

The preceding data analysis will provide the equilibrium data required to verify the performance curves shown in Figs. 5-1, 5-2, and 5-3. It should be emphasized that the method and calculations described in sections 5.1.1 and 5.1.2 are based upon two assumptions:

1. The analytic system loss coefficients are sufficiently accurate to characterize the RVACS performance, using the test operations matrix shown in Table 4-2.

2. The total heat transferred to the air coolant is accurately measured by $\dot{m}\, c_p\, (T_2 - T_1)$.

There are additional experiment measurements that will be used to verify the accuracy of these assumptions.

5.1.3.1 Velocity Calibrations

During the initial checkout of system operations, pitot-tube traverses will be made to map velocity profiles at several test section locations. These profiles will be used to calibrate the flow rake (VOLU-probe) transducer output discussed in Sections 3.3.3 and 3.3.4. It is expected that this calibration will be sufficiently accurate to provide accurate values of air heat input.

5.1.3.2 Pressure Loss Measurements

There are provisions to measure ΔPs across the test section (see Section 3.3.4). However, it should be recognized that these measurements are in the range of 10^{-2} to 10^{-3} psi and may be of doubtful value in characterizing system frictional losses. For example, the corrections required to compensate for cold air columns in the transducer lines are 5 to 10 times the magnitude of the desired measurements. Also, the total thermal driving head at maximum power is in the vicinity of 0.25 inches of H_2O. These measurements will be systematically recorded, however, to provide a basis for possible system frictional loss verifications.

5.1.3.3 Radiation Measurements

There are pre-calibrated radiometers (see Section 3.3.5) available to measure radiation heat flux independently and to determine guard vessel and duct wall emissivities.

6.0 EXTENDED OPERATIONS (PHASE III TEST OPERATIONS)

The phase III test operations refers to testing operations that would occur after a revised structural design configuration that would be based on an experimentally improved model and/or general modifications to the current design. Such revisions might include changing the entrance configuration and/or the exit weather cap, the channel air-gap spacing, and/or adding fins, ribs, or variable roughness.

7.0 QUALITY ASSURANCE

A quality assurance program plan for the ANL Shutdown Heat Removal Test Assembly was developed to describe the basic quality assurance requirements, which were used to assure that components, assemblies and subassemblies were designed, procured, fabricated, assembled and tested in accordance with standard engineering practices and/or specified acceptance criteria.[46] That QA plan is supplied in Appendix C of this document.

8.0 OPERATING PROCEDURES AND SAFETY

General operating procedures have been developed to maintain the integrity of experiments and equipment, and to emphasize and assure the safety of project personnel. The procedures and safety checks are discussed in this section. To implement the procedures and safety checks Experiment Log Worksheets have been developed, which are described in Appendix D. The worksheets describe the test conditions and requirements, and guide the execution of important tasks to be performed; the date, time, performer of the task, and the responsible engineer's approval (where applicable), are recorded on the forms. Additionally, periodic checks of the meteorological conditions will be recorded in the Experiment Log Worksheets. The Experiment Log Worksheets in Appendix D represent the initial format for implementation of the operating procedures and safety checks. It is anticipated that changes and/or additions will occur as experience is gained through performance of checkout tests.

The operating procedures and safety checks that are discussed below include three distinct phases involved in an experiment:

1. Pretest Operations (Section 8.1).

2. Operations During the Experiment (Section 8.2).

3. Posttest Operations (Section 8.3).

The personnel safety considerations of both general/mechanical and electrical natures are discussed in Sections 8.4 and 8.5 respectively.

8.1 Pretest Operations

The pretest operations include the following activites:

A. Verification that the appropriate flat plate damper is properly inserted.

B. Verification of appropriate fan and butterfly valve operation based on test requirements and conditions.

C. For the initial pretest checkout, and thereafter only as required, thermocouple resistance measurement checks will be made at the control console terminal box, and TC self-compensating reference devices will be operationally checked.

D. Heater series and parallel string resistance measurements will be recorded prior to each test operation.

E. Control console readiness verification as follows:

1. Control console power supplies and fan checks.

2. ISO-Paks/Unidriver and Unidriver/CAMAC interface checks.

3. Computer/DAS/CAMAC readiness check.

4. Alarm indicator (GFI, local, remote, and 480 VAC) checks.

5. Heater status (GFI alarm, 480 VAC, 20 channel) readiness checks.

6. Doric Data Loggers (3 units) readiness checks.

7. Instrumentation electronics readiness checks:

   a) MKS Baratron Unit #1.

   b) MKS Baratron Unit #2.

   c) Pressure transducer electronics panel.

   d) Barometer electronics panel.

e) Wind speed and azimuth electronics panel.

f) Humidity/temperature electronics panel.

g) Traverse mechanism electronics.

F. Safety interlocks operation verification.

Safety interlocks operational verifications will consist of the following checks:

1. Power interlocks on the access doors of the 480 V power-guard cage surrounding the heater side of the test section.

2. Interlock alarm and "Mars" light checks.

3. GFI checks.

G. Instrument calibration and/or zero adjustments.

1. MKS Baratron Unit #1 (VOLU-probe/rake Δp) zero check.

2. MKS Baratron Unit #2 (Test-Section Δp) zero check.

3. Pitot-static tube/shielded TC probe calibration check.

4. Radiometer/heat flux meter zero/calibration check.

5. Wind monitor zero/calibration check.

6. VOLU-probe/rake $\Delta p \rightarrow$ vel. $\rightarrow$ mass flow rate calibration check.

7. Traverse mechanism calibration.

H. Prepositioning of measurement instrumentation in test assembly.

1. Traverse mechanism containing pitot-static tube and radiation shielded thermocouple.

2. Radiometers (2 units) on duct wall.

3. Heat flux meters (2 threaded, gold plated sensors) on duct wall.

4. Emissivity probe in the side wall to measure duct wall emissivity.

5. Emissivity probe through the duct wall to measure G.V. wall emissivity.

I. It will be verified that the roll-up door is open, and appropriate "Restricted Area" signs, ropes, and/or lights are properly functional so that all entrances to test area are clearly marked as limited access entrances.

J. Test readiness visual inspection.

Visual inspections will be made to assure proper settings, alignment, and/or positioning of experimental apparatus; also, inspections will be made for openings in the system where air leakage could occur, for damage to wiring, insulation, or any other part of the Test Assembly, experimental apparatus, or auxiliary equipment. Verifications will be recorded to assure that entrances to the test area are functionally restricted as required, and that the test area is cleared of all non-essential materials, chemicals, equipment, tools, and especially papers, bags, clothing, plastic covering, and/or any item that is loose and light enough to be swept up into the heated test assembly by the large draft that will be created. Inspection of the Experiment Log is required for omissions, noted problems, and completeness, and verification is required that all electrical and electronic/computer control systems are in the readiness "go" mode. These visual inspections are required as pertains to the following areas:

1. Platform area.

2. Test section.

3. Inlet area.

4. Overall test area.

5. Control room.

8.2 Operations During the Experiment

A. Weather conditions will be recorded each and every hour after thermal equilibrium is established or when abrupt changes occur.

B. Relocation of the traverse mechanism, radiometers, heat flux meters, and emissivity probes will be performed as required and specified in the Experiment Log Worksheets.

C. A record will be kept of position relocations of the traverse mechanism, radiometers, heat flux meters, and emissivity probes as provided for in the Experiment Log Worksheets.

D. A record will be made in the Experiment Log of any abruptly obvious test assembly temperature, and/or flow rate changes, and especially if concurrent atmospheric changes occur.

E. Operation of the building exhaust fan is permitted for removing outgassed smoke and fumes only as deemed necessary during the initial heater bake-out. The exhaust fan will not be used during the system performance testing operations unless it is urgenly required to remove smoke, fumes, and/or heat; in that case, the effect on the system's temperature, pressure, velocity, air-mass flow rate, and overall performance will need to be assessed, and recorded in the Experiment Log.

F. Performance of other tasks may be required based on the type of test, mode of operation, conditions, requirements, or other considerations.

G. Experiment operations are completed, and power-down is initiated only after the Experiment Log Worksheets are reviewed by the responsible test engineer, lead experimenter, project manager, or a designated representative, and such person's signature approval is given to power-down.

8.3 Posttest Operations

A. Once approval to power-down is properly obtained, and the system is at zero power, posttest operations are begun.

B. The control console shut-down procedures are performed only after the temperature of the test section is reduced to below 100°F.

C. The test area posttest procedures will include operation of the forced-flow fan with the butterfly valve fully open, and a flow restricting flat-plate damper inserted to restrict the air flow in through the upper chimney outlet. The roll-up door will need to remain open during the cool-down operation, and the test area will be manned until the temperature of the test section is reduced to below 100°F, at which time the final shutdown procedures will commence.

D. Final Shutdown Procedures

1. When the test section has cooled to about 100°F the fan should be turned off, and the butterfly valve damper closed.

2. After the test assembly has cooled to about 90°F the solid plate damper should be inserted.

Note: This operation is anticipated to be required primarily during the cold seasons (autumn, winter, and spring) to restrict the natural convective flow of warm room air out through the chimney.

3. The roll-up door may be closed gradually as the test assembly cools and the air draft demand decreases (especially during cold, and inclement weather).

4. Completion of the "on-line" data reduction, and hard copy data graphing will be performed and verified as required; also, the test data recorded on the DAS winchester disk will be copied to 8-in. floppy disks (type RX02 or RX01).

5. Completion of the final shutdown procedures for the control console will be performed.

6. It shall be verified that all the test data required to be saved has been copied to floppy disks, the disks are properly labeled, and stored in appropriate carrying containers.

8.4 Personnel Safety - General/Mechanical

Personnel safety has been a major objective in the construction, assembly, and operation of the Test Assembly. The personnel safety considerations of general/mechanical nature, are described below:

1. Guard railings have been installed at all access areas above ground level.

2. Safety ladders with encagements have been installed for climbing to access areas.

3. The test area is a designated "limited access" area where only those persons authorized are allowed access.

4. The test area is a designated "hard hat area" for protection from falling objects while working in that area.

5. Safety belts and safety lines are used by personnel when performing tasks much above floor level.

6. "Restricted area" warning rope, signs, and/or lights will be located at the roll-up door entrance, and the other entrances to the test area where deemed necessary for the protection of personnel and others during test operations.

7. Respirators that cover the nose and mouth are worn by personnel whenever cutting and/or working with the insulation material.

8. The insulation material is cut to size inside an exhaust hood and special canopied area.

9. A special multi-filtered vacuum cleaner is used for cleaning up insulation cuttings and dust, and the insulation is painted with a special paint to freeze the dust from forming by simple abrasion.

10. To assure personnel safety and the proper conduct of experiments testing procedures worksheets will be completed and approved by responsible personnel for the safe and proper conduct of all experiment operations.

11. To protect personnel from receiving burns or other injuries during position transfers of the hot pitot-tube/TC-probe traverse mechanism, radiometers, heat flux meters, or emissivity measurement probes, insulated heat resistant gloves, face shields, and heat resistant clothing will be worn.

12. After the system is energized, a team of at least two persons will be required in the test area for any work related activity around the test assembly.

8.5 Personnel Safety - Electrical

Personnel safety considerations of an electrical nature that have been attended to are listed below:

1. Protection against electrical shock at 480 V terminals is provided for with cover guards, and locked access panel doors; each such terminal is clearly tagged with approved warning tags, and wherever necessary warning signs, rope, or tape is utilized to bring attention to the potential danger of high voltage.

2. Two power "scram" devices, one on the main floor level near the test assembly, and one near the control console, are clearly identified, and conveniently located for quick access near areas of high potential danger primarily from 480 V electrical shock.

3. Continuity of electrical grounds is assured through the use of grounding cables. Their location, type, and relationship with other "grounds" in the grounding network is clearly indicated with the use of sign tags. Procedures for testing and certifying the integrity of electrical grounds are provided.

4. Heaters are ground fault protected.

5. Heater power will be electrically disconnected due to:

    a. GFI

    b. Interlock Alarm

    c. Emergency Scrams as follows:

        1. Local at console (one switch near console for heaters only).

2. Remote at experiment (one button on main floor next to test assembly).

d. Heater over temperature.

6. A smoke alarm is located near the test assembly, which is part of the ANL Fire Department's building alarm system.

7. A "Mars" light power-on indicator is installed in a centrally conspicuous location in the experiment area.

8. All 480 volt wiring is either insulated or contained within a containment that provides personnel protection.

9. Heater power requires a keyswitch to activate.

10. All experiment steel support structures are grounded with a braided ground wire directly to a driven earth ground. Ground straps are rated at least AWG #0. The control console is grounded to the transformer ground.

11. General 110V service power for experiment related considerations will be electrically isolated from heater power.

9.0 DOCUMENTATION SUMMARY

The following is a list of the primary documents, excluding important memos, relating to the ANL RVACS/RACS Shutdown Heat Removal Test Assembly:

Dwg./Spec. No.	Title
R0408-1000-SA	Design Requirements for the Shutdown Heat Removal Test Assembly
R0408-1001-DN	Shutdown Heat Removal Test Assembly Miscellaneous Scoping Calculations
R0408-1002-DU	Shutdown Heat Removal Test Assembly Component Characteristic Summary

R0408-1003-SA-01	Quality Assurance Program Plan for the Shutdown Heat Removal Test Assembly
R0408-1004-SE	Shutdown Heat Removal Test Assembly Service Platform Design and Calculations
R0408-1005-SF	Operation Process Work Sheets for the Shutdown Heat Removal Experiment Assembly
Design Review Doc. (9/19/85)	RVACS/RACS Instrumentation - Requirements and Recommendations
R0408-0004-PL-00	Shutdown Heat Removal Test Assembly - Parts List
R0408-0004-DE-00	Shutdown Heat Removal Test Assembly
R0408-0006-DD-01	Base Support Weldment
R0408-0008-PL-01	Test Section 1 Case I Subassembly - Parts List
R0408-0008-DD-01	Test Section 1 Case I Subassembly
R0408-0010-DD-00	Heater Plate Subassembly
R0408-0012-DD-00	Test Section Weldment
R0408-0101-DD-01	Mounting Plate
R0408-0014-DD-00	Insulation Subassembly
R0408-0107-DD-02	Vertical Full Duct Section
R0408-0108-DD-02	Vertical Short Duct Section
R0408-0110-DD-00	Tee Section Duct
R0408-0113-DD-00	Valve/Tee Duct Section
R0408-0114-DD-00	Fan/Valve Duct Section
R0408-0023-DD-00	Fan Exhaust Duct
R0408-0139-DE-00	Extended Elbow
R0408-0137-DE-00	Upper Elbow
R0408-0157-DE-01	Thru Roof Duct Section
R0408-0162-DE-00	Intermediate Chimney Duct
R0408-0166-DE-00	Top Chimney Duct
Advance Copy	Weather Cap
R0408-0400-DE	Electrical System Diagram
R0408-0401-DD	Instrumentation Block Diagram
R0408-0031-DD	Traverse Mechanism Assembly
R0408-0032-DD	Heat Flux and Emissivity Sensor Assemblies

Design Review: Personal Communication, R. A. Noland, H. J. Haupt and R. W. Seidensticker (September, 1985).

Personal Communication, R. W. Seidensticker and L. E. Garrison (November, 1985).

Personal Communication, H. J. Haupt, R. W. Seidensticker, and L. E. Garrison (May 1986).

Safety Review: Personal Communication, J. B. Heineman and D. R. Armstrong (October, 1986).

Personal Communication, R. C. Doerner to Distribution, (October, 1986).

Personal Communication, J. B. Heineman, D. R. Armstrong and W. R. Rupp, (November, 1986).

Personal Communication, W. A. Rupp and J. B. Heineman, (November, 1986).

10.0 PROJECT ORGANIZATION

The organizational responsibilities of personnel assigned to the project are illustrated in the project organization chart shown in Fig. 10-1. A large effort was required from the mechanical and electrical systems personnel in the fabrication, construction, and assembly of the Test Assembly, and the actual performance of tests. Test analyses, planning and design requirements are the responsibility of the lead experimenter, the pre-test analysis group, project manager and program manager. Progress in the various aspects of the project is communicated to the project and program managers during a weekly meeting with responsible personnel, and a memo of the minutes and action items from that meeting is distributed to all responsible project personnel.

Project Organization - RVACS/RACS Air-Side Performance Tests

9/23/86
Rev. 2

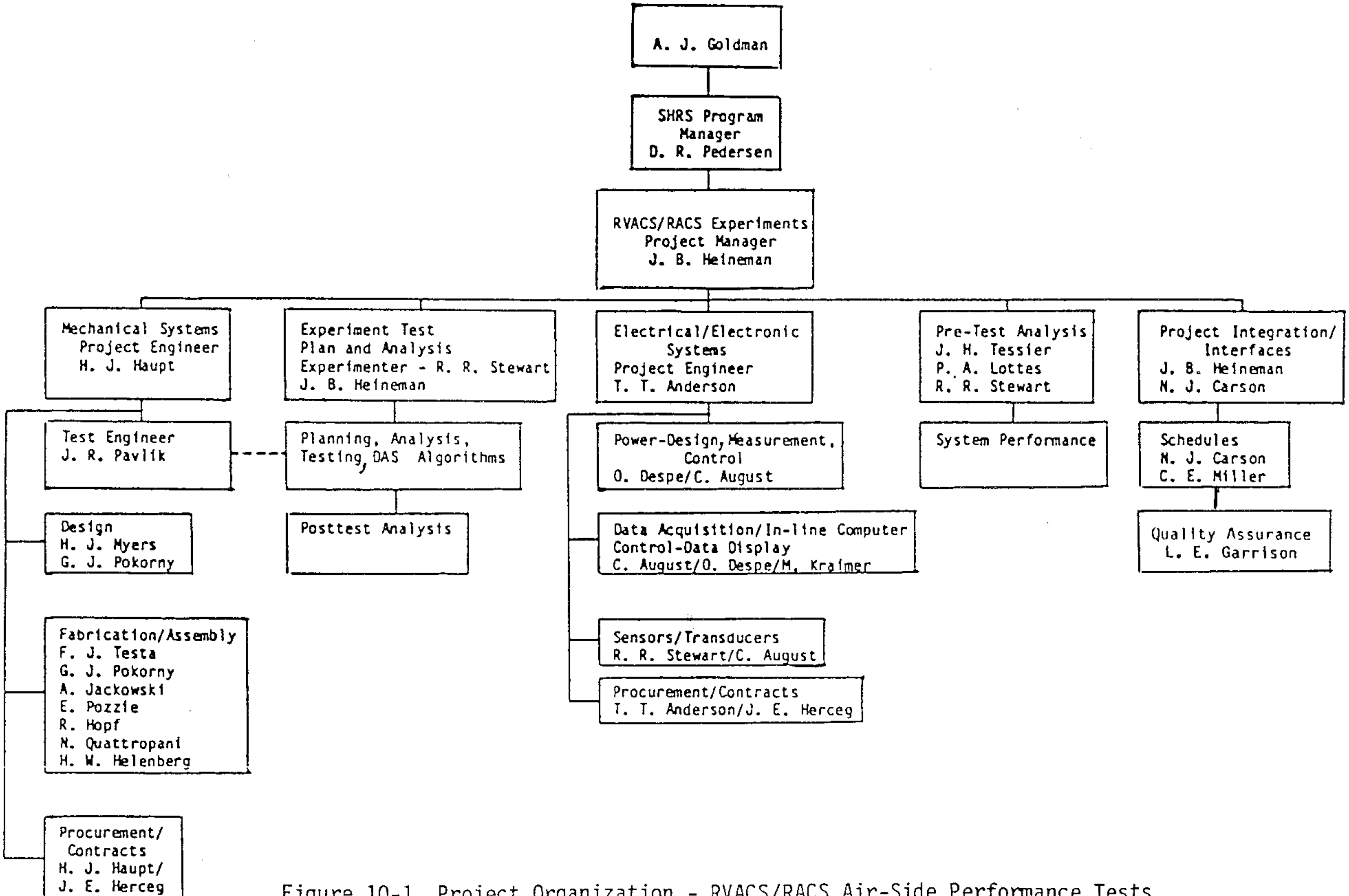


Figure 10-1. Project Organization - RVACS/RACS Air-Side Performance Tests.

REFERENCES

1. General Electric Company, Unpublished Report (1983).

2. General Electric Company, Unpublished Report (1984).

3. General Electric Company, Unpublished Report (1984).

4. T. C. Chawla, et al., "Modeling of the Air-Side Performance of the RVACS Shutdown Heat Removal System - Status of Experimental Program," ANL-PRISM-8 (January 1986).

5. F. B. Cheung, R. R. Stewart, D. R. Pedersen, and J. H. Tessier, "Design Requirements for the Shutdown Heat Removal Test Assembly," ANL Spec. #R0408-1000-SA-00 (June 1985).

6. D. R. Pedersen to Distribution, Personal Communication (February 1986).

7. J. B. Heineman, R. R. Stewart, and D. R. Pedersen, Personal Communication (April 1986).

8. J. B. Heineman and R. R. Stewart to Distribution, Personal Communication (August 1986).

9. Comments Made at Design Review of the ANL Shutdown Heat Removal Test Assembly (September 19, 1985).

10. H. J. Haupt to Distribution, Personal Communication (May 1986).

11. R. R. Stewart to Distribution, Personal Communication (May 1986).

12. P. A. Lottes to Distribution, Personal Communication (May 1986).

13. P. A. Lottes to Distribution, Personal Communication (May 1986).

14. P. A. Lottes to Distribution, Personal Communication (May 1986).

15. J. H. Tessier to Distribution, Personal Communication (May 1986).

16. J. H. Tessier to Distribution, Personal Communication (May 1986).

17. J. H. Tessier to Distribution, Personal Communication (July 1986).

18. P. A. Lottes, unpublished data, (August 1986).

19. I. E. Idelchik, et al., "Handbook of Hydraulic Resistances," Hemisphere Publishing Co. (1986).

20. D. S. Clark and W. R. Varney, "Physical Metallurgy for Engineers," D. Van Nostrand Co., p. 532 (1962).

21. General Electric Handbook - Heat Transfer Div. (source) J. Poggie, "Radiation Characteristics of Metals," Product Engineering, p. 205-207 (September 1953).

22. S. M. DeLorso and R. L. Coit, "Measurement of Total Emissivities of Gas-Turbine Combustor Materials," The American Society of Mechanical Engineers Transactions, Vol. 77, pp. 1189-1197 (1955).

23. H. J. Haupt, "Shutdown Heat Removal Test Assembly Component Characteristic Summary," ANL Doc. No. R0408-1002-DU-00, Refractory Products Company, 770 Tollgate Rd., Elgin, IL 60120 (CPC-X ceramic fiber board), p. 44-49 (August 1985).

24. Elgo Shutter Manufacturing Company (Division of Industries Air Inc.), P. O. Box 215, Bach-Baxton Rd., Amelia, OH, 45102.

25. J. H. Tessier to Distribution, Personal Communication (May 1986).

26. A. N. Lowing, ANL/PFS, "Shutdown Heat Removal Test Assembly Service Platform Design Details and Calculations," ANL Spec. No. R0408-1004-SE-00 (December 18, 1985).

27. H. J. Haupt, "Shutdown Heat Removal Test Assembly Component Characteristic Summary," ANL Spec. No. R0408-1002-DU-00, pp. 4-8 (August 1985).

28. Claud S. Gordon Co., Richmond, IL.

29. Manual On The Use of Thermocouples in Temperature Measurement, ASTM STP470B, Tech. Pub., p. 164 (1981).

30. Aremco Products, Inc., P. O. Box 429, Ossining, NY 10562.

31. R. R. Stewart to Distribution, Personal Communication (September 1985).

32. R. R. Stewart and J. B. Heineman, Personal Communication (September 1986).

33. R. R. Stewart and J. B. Heineman, Personal Communication (June 1986).

34. R. R. Stewart to Distribution, Personal Communication (June 1986).

35. E. O. Doebelin, "Measurement Systems: Application and Design," McGraw-Hill, p. 438 (1966).

36. R. G. Folsom, "Review of the Pitot Tube," Trans. ASME, p. 1450 (October 1956).

37. Air Monitor Corp., P. O. Box 6358, Santa Rosa, CA 95406.

38. MKS Instruments, Inc., 34 Third Ave., Burlington, MA 01803.

39. R. R. Stewart and J. B. Heineman, Personal Communication (July 1986).

40. Midtherm Corp., P. O. Box 412, Huntsville, AL 35804.

41. Velmex, Inc., P. O. Box 38, E. Bloomfield, NY 14443.

42. R. R. Stewart and J. B. Heineman, Personal Communication (July 1986).

43. R. M. Young Co., Aero-Park Drive, Traverse City, MI 49684.

44. T. T. Anderson to Distribution, Private Communication (July 1986).

45. Kane-May Measuring Instruments, 6643 Terrace No., West Palm Beach, FL 33407.

46. J. P. Holman, "Heat Transfer," 2d Ed., McGraw-Hill, p. 199 (1968).

47. W. H. McAdams, "Heat Transmission," 3d Ed., McGraw-Hill, (1954).

48. Quality Assurance Program Plan for Shutdown Heat Removal Test Assembly, Specification No. R0408-1003-SA-01 (December 1985).

APPENDIX A

Midtherm Corporation
Radiometers and Heat Flux Transducers
Calibration Curves, and Certificates of
Calibration

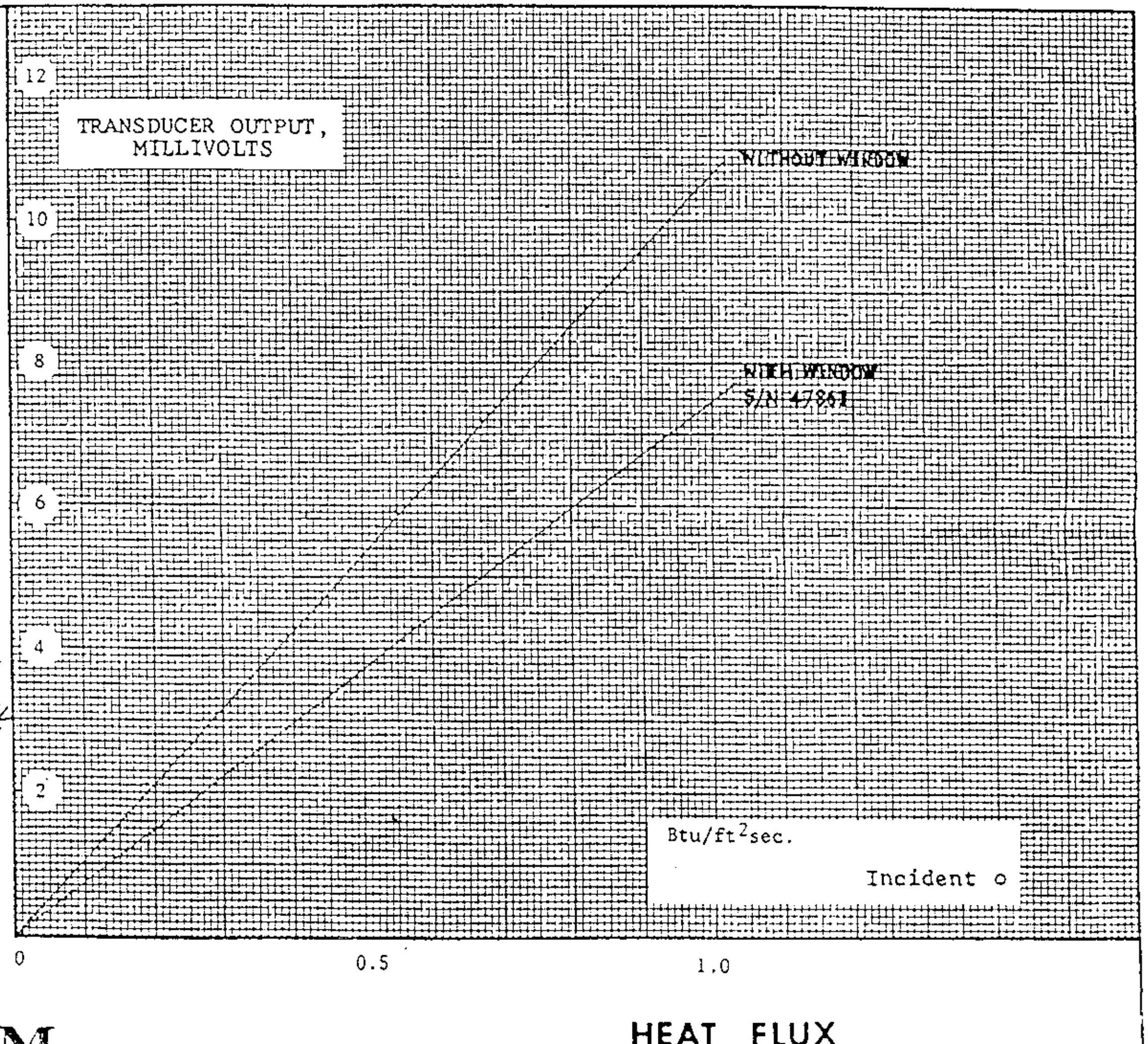
CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Lab
CUSTOMER P.O. 60510078
MODEL NO. 64-1.0-10MgO-36-20X/KRS5W-1C-150
SERIAL NO. 47861
ABSORPTIVITY 0.97
WINDOW TYPE KRS-5

REFERENCE STANDARD 99440
TESTED BY FB
QC ACCEPTANCE MEDTHERM INSPECT NO. 2 TEST ACCEPT

CERTIFIED CALIBRATION
SUBSCRIBED AND SWORN TO BEFORE ME THIS 10th DAY OF July 1986
Glenda Conner

GLENDA CONNER NOTARY PUBLIC ALABAMA STATE AT LARGE



MEDTHERM CORPORATION
POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Lab
CUSTOMER P.O. 60510078
MODEL NO. 64-1.0-10MgO-36-20K/KRS5W-1C-150
SERIAL NO. 47862
ABSORPTIVITY 0.97
WINDOW TYPE KRS-5

REFERENCE STANDARD 99440
TESTED BY FB
QC ACCEPTANCE MEDTHERM INSPECT NO. 2 TEST ACCEPT

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SUBSCRIBED AND SWORN TO BEFORE ME THIS 10th DAY OF July 19 86

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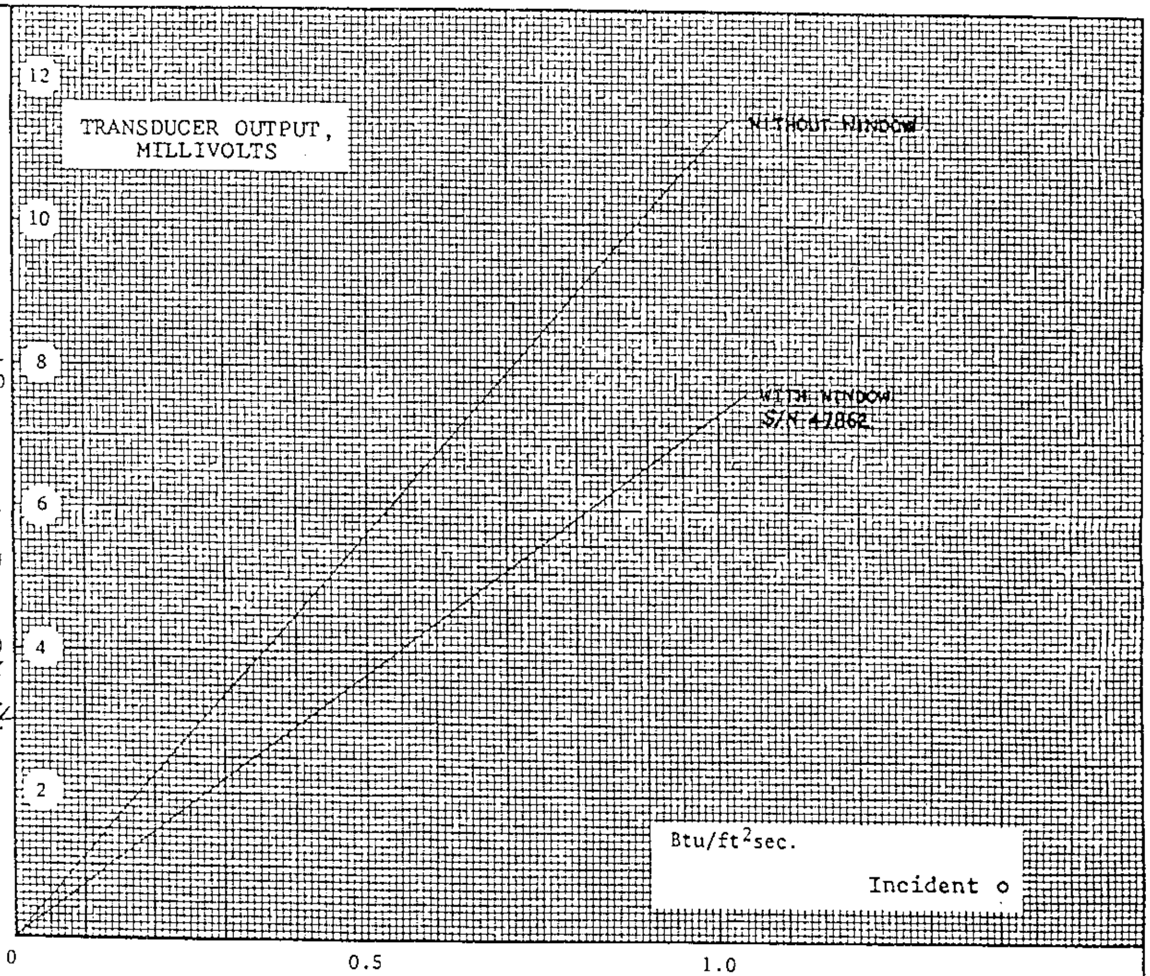

HEAT FLUX

MEDTHERM CORPORATION POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Labs
CUSTOMER P.O. 60510078
MODEL NO. 24-1.0-36MgO-36-18K/KRS5W
SERIAL NO. 73861
ABSORPTIVITY 0.97
WINDOW TYPE KRS-5

REFERENCE STANDARD 99340
TESTED BY FB
QC ACCEPTANCE TEST ACCEPT

MEDTHERM INSPECT NO. 2

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SUBSCRIBED AND SWORN TO BEFORE ME THIS 10th DAY OF July 19 86

Glenda Conner

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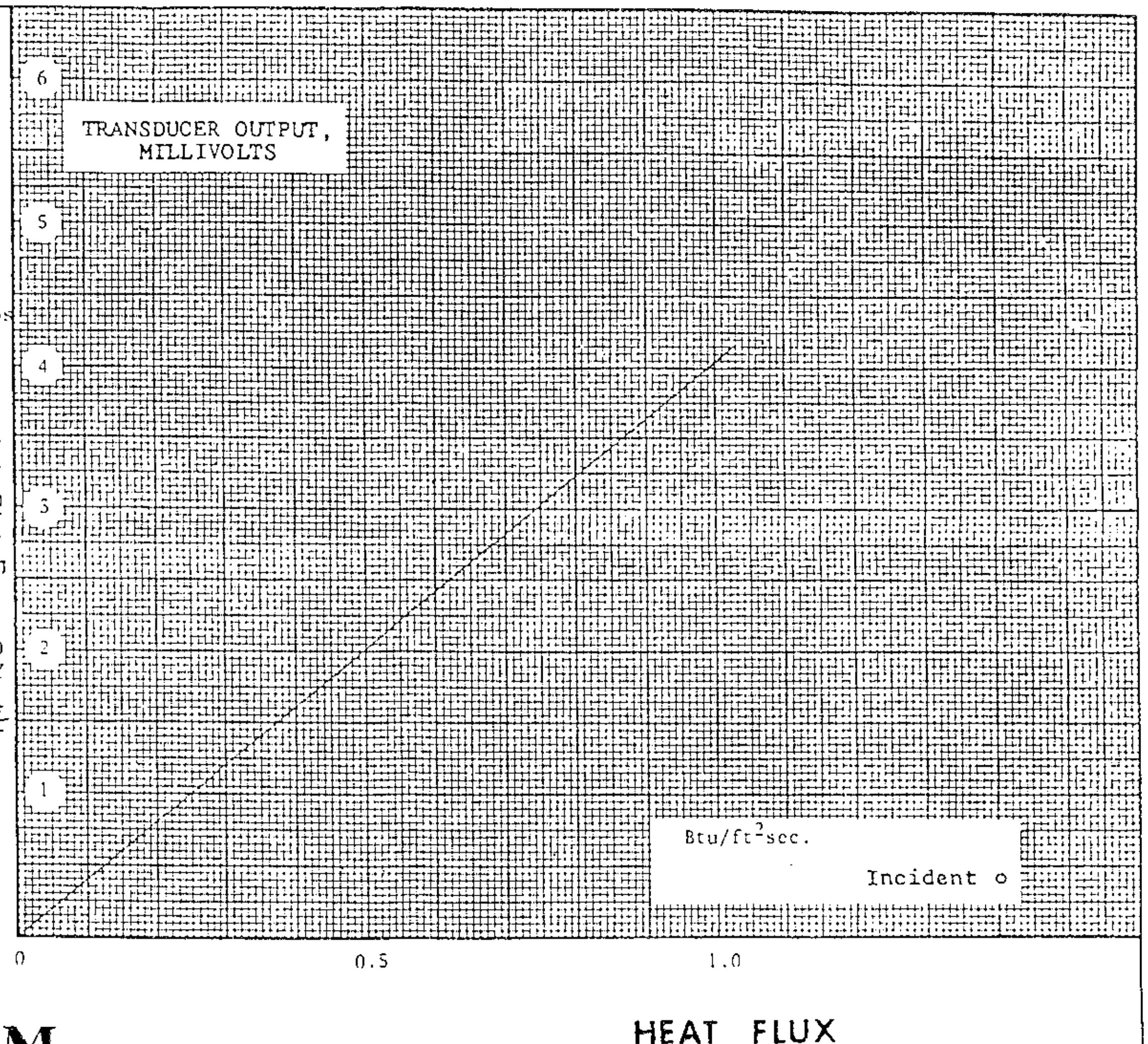

MEDTHERM CORPORATION
POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Lab
CUSTOMER P.O. 60510078
MODEL NO. 24-1.0-36MgO-36-18K/KRS5W
SERIAL NO. 73862
ABSORPTIVITY 0.97
WINDOW TYPE KRS-5

REFERENCE STANDARD 99440
TESTED BY FB
QC ACCEPTANCE TEST ACCEPT
MEDTHERM INSPECT NO. 2

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OF July 1986
Glenda Conner

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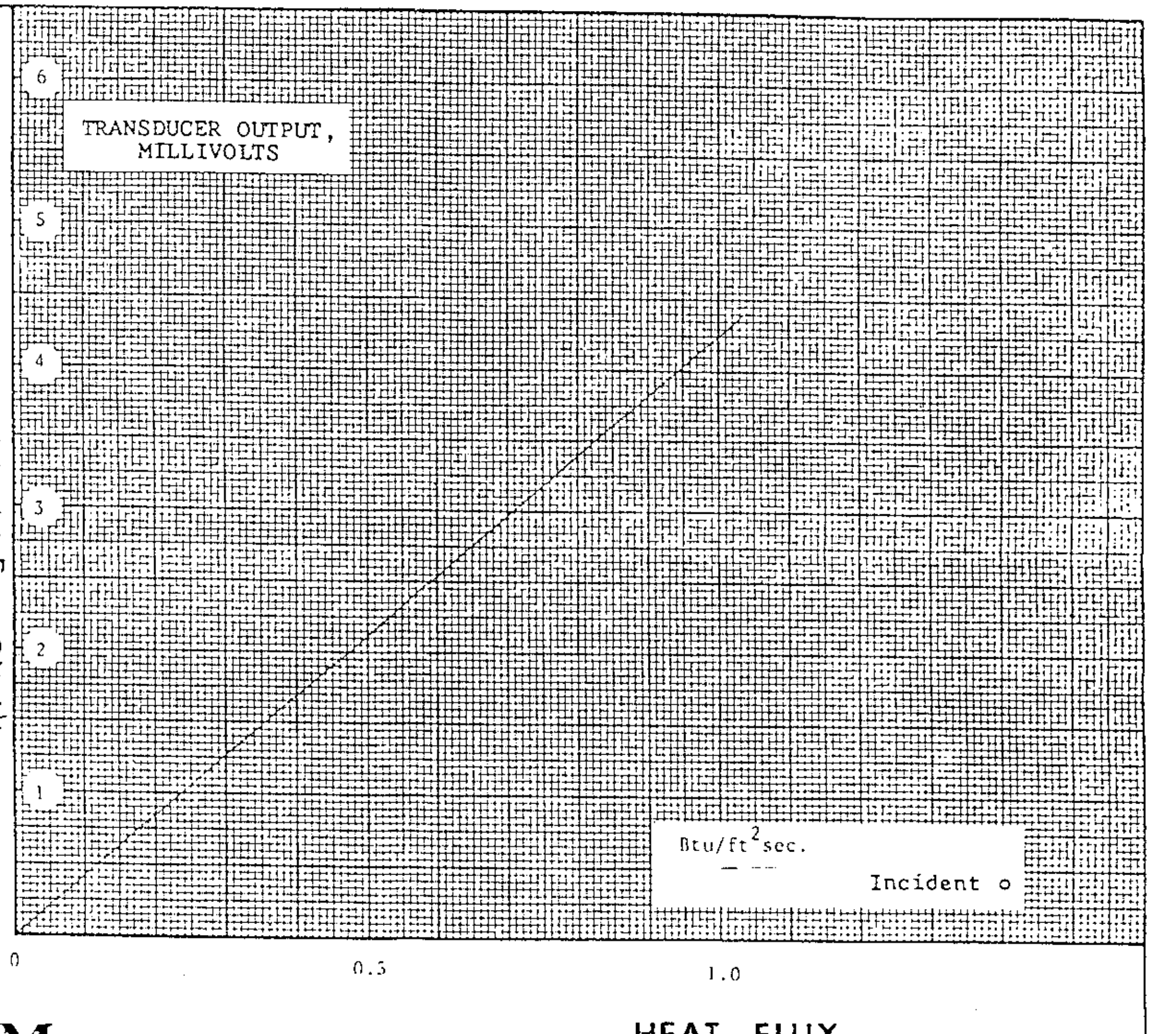

MEDTHERM CORPORATION
POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Lab
CUSTOMER P.O. 60510078
MODEL NO. 40-0.875-1.0-10MgO-36-20681KGP
SERIAL NO. 47865
ABSORPTIVITY -
WINDOW TYPE None

REFERENCE STANDARD 99440
TESTED BY FB
QC ACCEPTANCE TEST ACCEPT MEDTHERM INSPECT NO. 2

CERTIFIED CALIBRATION
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Glenda Conner

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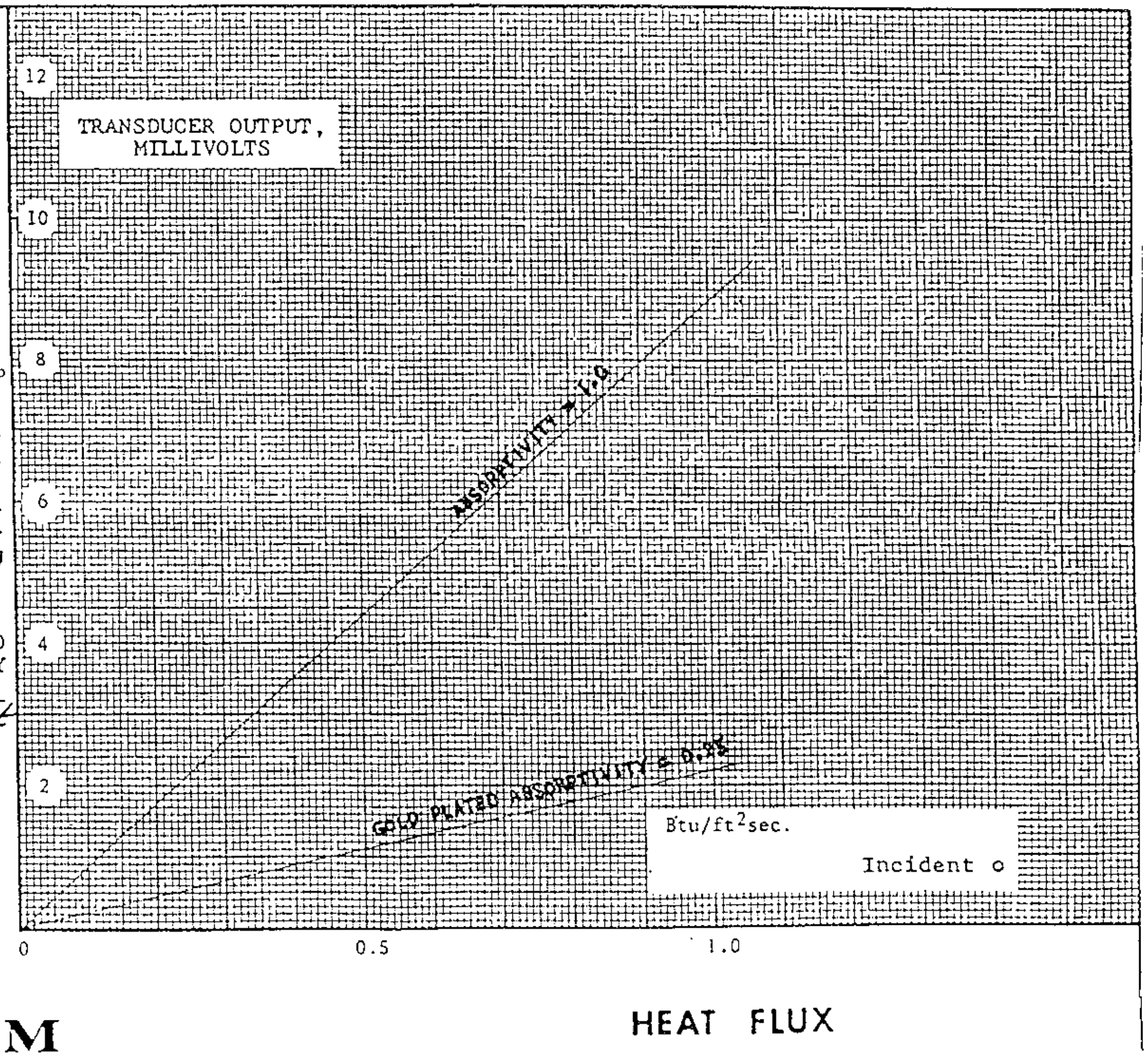

MEDTHERM
CORPORATION

POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

CERTIFICATE OF CALIBRATION

DATE 7/10/86
CUSTOMER Argonne Nat'l Lab
CUSTOMER P.O. 60510078
MODEL NO. 40-0.875-1.0-10MgO-36-20681KGP
SERIAL NO. 47866
ABSORPTIVITY -
WINDOW TYPE None

REFERENCE STANDARD 99440
TESTED BY FB
QC ACCEPTANCE MEDTHERM INSPECT NO. 2 TEST ACCEPT

CERTIFIED CALIBRATION
SUBSCRIBED AND SWORN TO
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OF July 19 86

Glenda Conner

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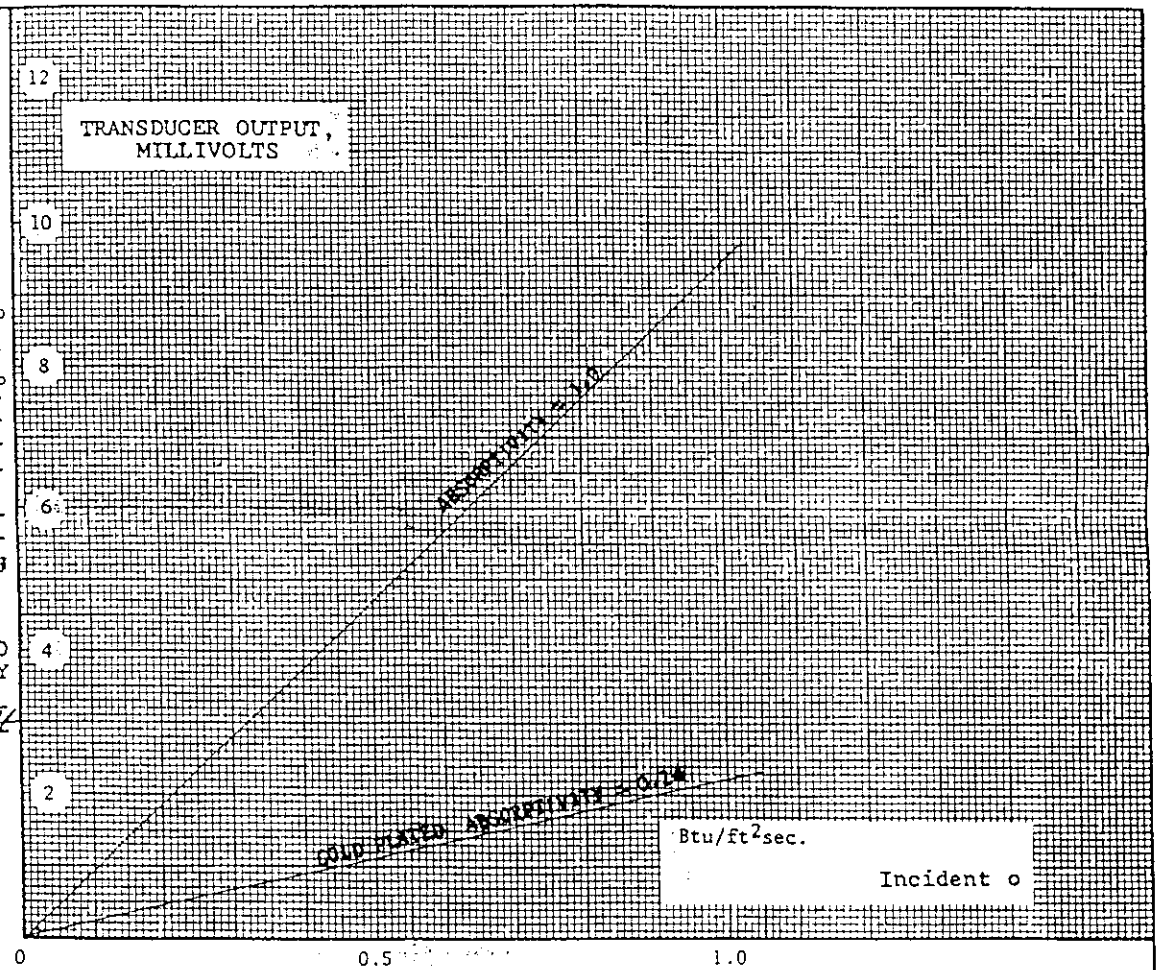


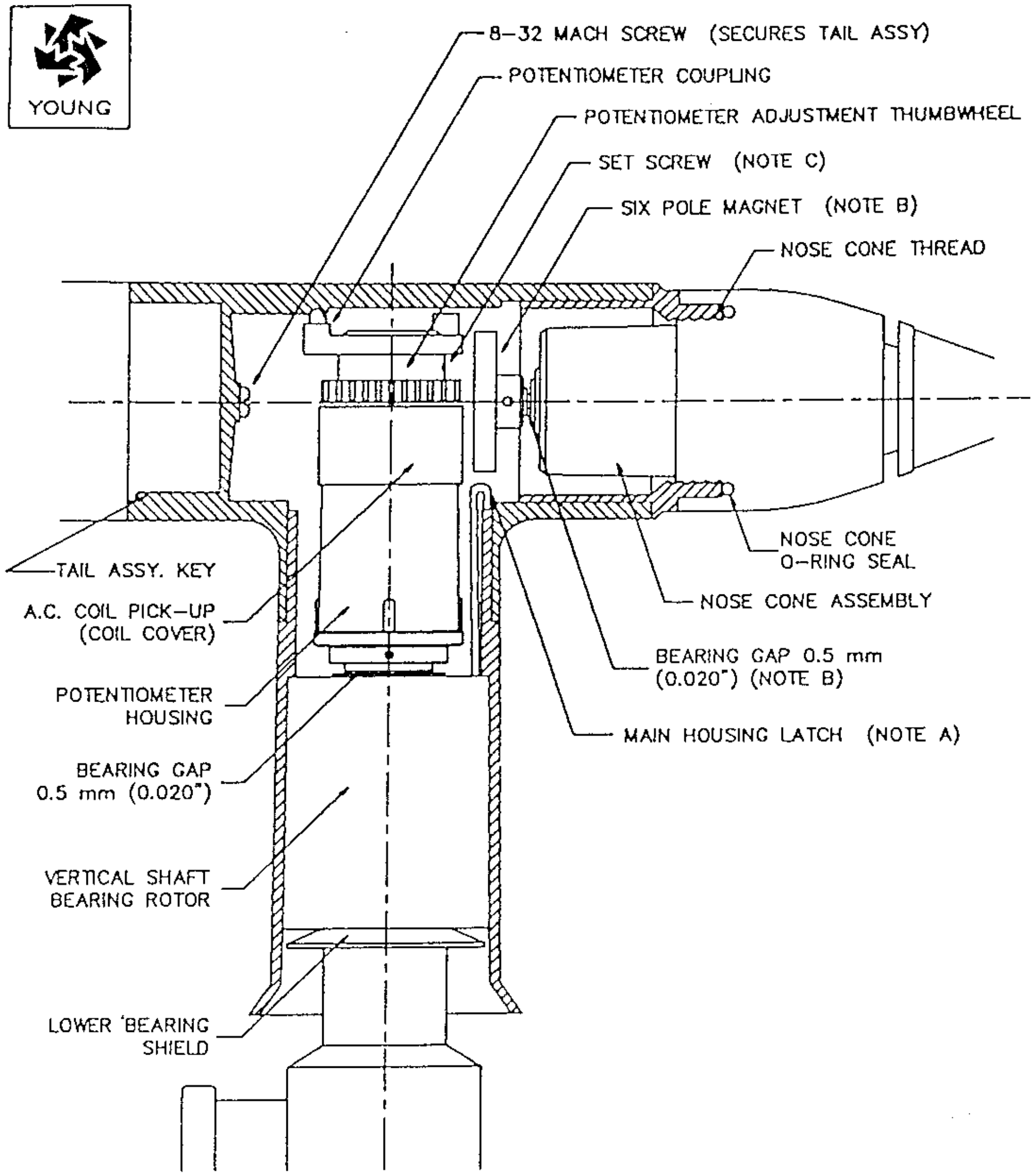
HEAT FLUX

MEDTHERM CORPORATION POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

APPENDIX B

R. M. Young Company
Wind Monitor Calibration Curves
and Pertinent Information

YOUNG



NOTE:

A. TO REMOVE MAIN HOUSING – UNTHREAD NOSE CONE ASSEMBLY, PUSH MAIN HOUSING LATCH, LIFT UPWARD.

B. TO REPLACE ANEMOMETER BEARINGS – UNTHREAD NOSE CONE, REMOVE SIX POLE MAGNET, SLIDE PROPELLER SHAFT AND HUB ASSEMBLY FORWARD. AFTER BEARING REPLACEMENT, SET BEARING GAP TO 0.5mm (0.020")

C. TO ADJUST POTENTIOMETER OUTPUT SIGNAL – REMOVE NOSE CONE, LOOSEN SET SCREW IN POTENTIOMETER COUPLING, ADJUST OUTPUT SIGNAL BY MEANS OF POTENTIOMETER ADJUSTMENT THUMBWHEEL, RE-TIGHTEN SET SCREW.

MODEL 05103	*OCT 85*
WIND MONITOR	*M05103M*
SECTION VIEW – MAIN HOUSING/TRANSDUCER ASSY.	
R. M. YOUNG CO. TRAVERSE CITY, MI 49684 U.S.A. 616-946-3980	

JAN 79

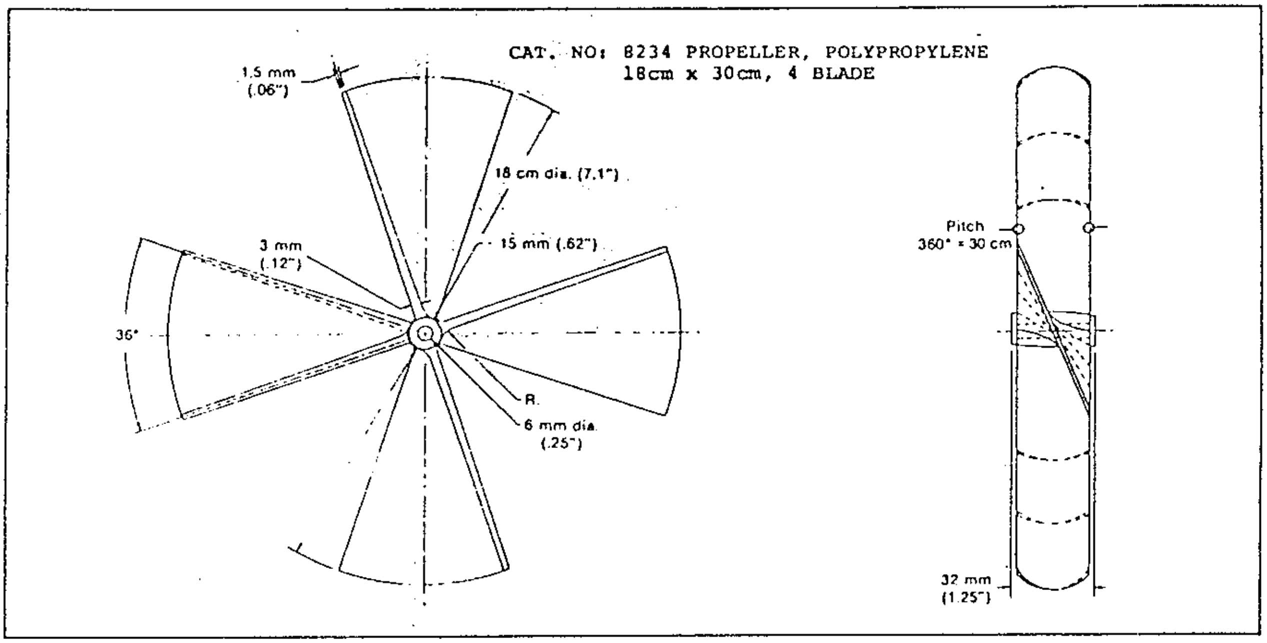
YOUNG

HIGH RESOLUTION PROPELLER

These injection molded thermoplastic propellers are intended for direct substitution for the polystyrene 4 blade propellers for applications requiring greater physical strength as well as an extended working range. They may be used in place of the sensitive polystyrene 4 blade propellers without significant change in calibration. Cosine response is also similar.

The helicoid shape 18cm diameter x 30cm pitch propeller is a one piece molding of polypropylene plastic with a specific gravity of 0.9, resulting in a total weight of 31gm (1.1 oz). Distance constant is 3.3m (10.5 ft). (Distance constant is the wind passage required for 63% recovery from a step change in wind speed.) Polypropylene is a very flexible and durable material making this propeller highly resistant to failure from high winds as well as icing and hail damage.

Working range is 0-50m/s (112mph). Threshold is 0.2-0.4m/s (0.5-0.9mph). Threshold is measured with the propeller mounted on a standard sensor with precision instrument grade ball bearings and driving a miniature tachometer generator.



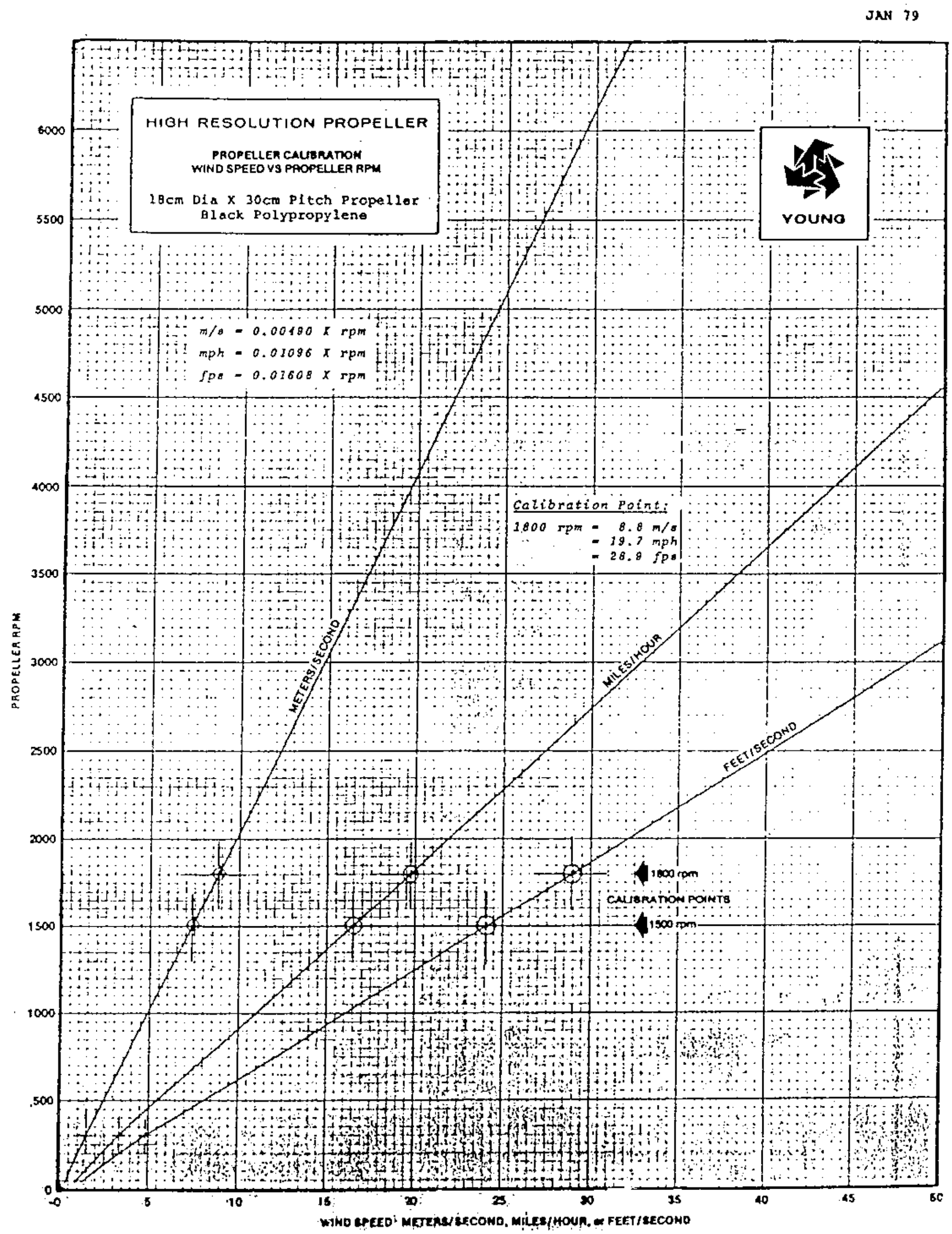
SPECIFICATIONS:

RANGE - AXIAL FLOW:	50 m/s (112 mph)
RANGE - ALL ANGLE:	50 m/s (112 mph)
THRESHOLD:	0.2 - 0.4 m/s (0.5 - 0.9 mph)
DISTANCE CONSTANT:	3.3m (10.5 ft.)
EFFECTIVE PITCH:	29.4cm (0.96 ft.)
WORKING TEMPERATURE:	120°C (248°F)
MATERIAL:	POLYPROPYLENE (SPECIFIC GRAVITY 0.9)

CALIBRATION POINTS:

HORIZONTAL -	3600 rpm	17.6 m/s	(39.5 mph)
	3000 rpm	14.7 m/s	(32.9 mph)
	1800 rpm	8.8 m/s	(19.7 mph)
	1500 rpm	7.4 m/s	(16.4 mph)
	300 rpm	1.5 m/s	(3.4 mph)
	250 rpm	1.2 m/s	(2.7 mph)
VERTICAL -	1800 rpm	11.0 m/s	(24.6 mph)
	1500 rpm	9.3 m/s	(20.8 mph)
	300 rpm	1.8 m/s	(4.0 mph)
	250 rpm	1.5 m/s	(3.4 mph)

R.M. YOUNG COMPANY
2801 Aero-Park Drive, Traverse City, MI 49684, U.S.A.
Phone (616) 946-3980 TWX 810-291-3366


JAN 79
HIGH RESOLUTION PROPELLER
PROPELLER CALIBRATION
WIND SPEED VS PROPELLER RPM
18cm Dia X 30cm Pitch Propeller
Black Polypropylene
YOUNG
m/s = 0.00490 X rpm
mph = 0.01096 X rpm
fps = 0.01608 X rpm
Calibration Point:
1800 rpm = 8.8 m/s
= 19.7 mph
= 28.9 fps
METERS/SECOND
MILES/HOUR
FEET/SECOND
1800 rpm
CALIBRATION POINTS
1500 rpm
PROPELLER RPM
WIND SPEED METERS/SECOND, MILES/HOUR, or FEET/SECOND
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
5
10
15
20
25
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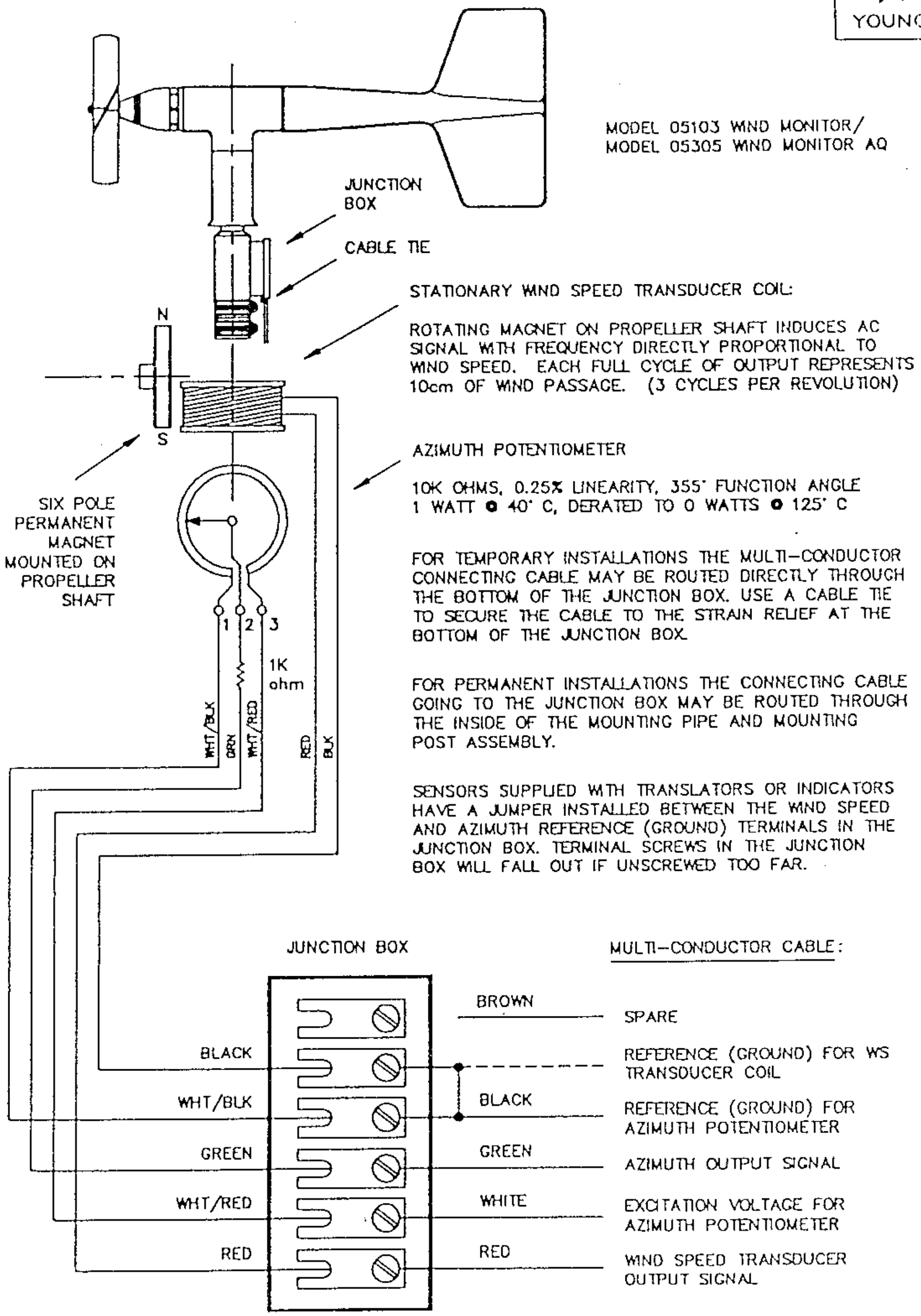
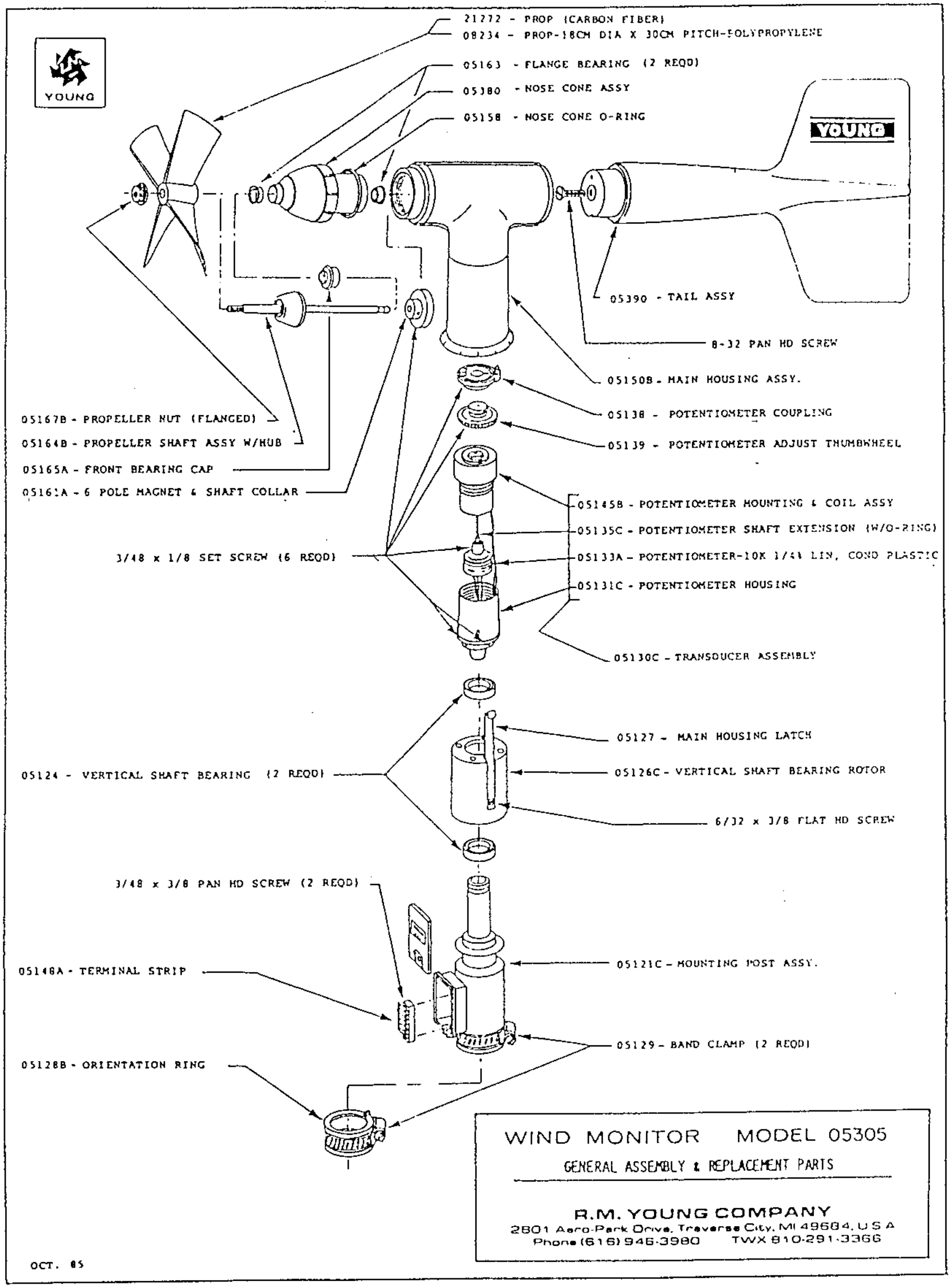
35
40
45
50

YOUNG



MODEL 05103/05305	*OCT 85*
WIND MONITOR/WIND MONITOR AQ	*W05103*
CABLE AND WIRING DIAGRAM	
R. M. YOUNG CO. TRAVERSE CITY, MI 49684 U.S.A. 616-946-3980	


YOUNG
21272 - PROP (CARBON FIBER)
08234 - PROP-18CM DIA X 30CM PITCH-POLYPROPYLENE
05163 - FLANGE BEARING (2 REQD)
05380 - NOSE CONE ASSY
05158 - NOSE CONE O-RING
YOUNG
05390 - TAIL ASSY
8-32 PAN HD SCREW
05150B - MAIN HOUSING ASSY.
05138 - POTENTIOMETER COUPLING
05139 - POTENTIOMETER ADJUST THUMBWHEEL
05167B - PROPELLER NUT (FLANGED)
05164B - PROPELLER SHAFT ASSY W/HUB
05165A - FRONT BEARING CAP
05161A - 6 POLE MAGNET & SHAFT COLLAR
05145B - POTENTIOMETER MOUNTING & COIL ASSY
05135C - POTENTIOMETER SHAFT EXTENSION (W/O-RING)
3/48 x 1/8 SET SCREW (6 REQD)
05133A - POTENTIOMETER-10K 1/4% LIN, COND PLASTIC
05131C - POTENTIOMETER HOUSING
05130C - TRANSDUCER ASSEMBLY
05127 - MAIN HOUSING LATCH
05124 - VERTICAL SHAFT BEARING (2 REQD)
05126C - VERTICAL SHAFT BEARING ROTOR
6/32 x 3/8 FLAT HD SCREW
3/48 x 3/8 PAN HD SCREW (2 REQD)
05121C - MOUNTING POST ASSY.
05148A - TERMINAL STRIP
05129 - BAND CLAMP (2 REQD)
05128B - ORIENTATION RING
WIND MONITOR MODEL 05305
GENERAL ASSEMBLY & REPLACEMENT PARTS
R.M. YOUNG COMPANY
2801 Aero-Park Drive, Traverse City, MI 49684, U.S.A.
Phone (616) 946-3980 TWX 810-291-3366
OCT. 85

APPENDIX C

Quality Assurance Program Plan for the Shutdown Heat Removal Test Assembly

Argonne National Laboratory
9700 S. Cass Avenue
Argonne, Illinois 60439

REACTOR ANALYSIS AND SAFETY DIVISION

QUALITY ASSURANCE PROGRAM PLAN
for the
Shutdown Heat Removal Test Assembly

R0408-1003-SA-01

December, 1985

Revised - April, 1986

Prepared by: L. Harrison Date 12/13/85
RAS / Quality Assurance Engineer

Reviewed by: H. James Stang Date 12/17/85
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Reviewed by: G. S. Stewart Date 1/15/86
Experimenter

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N. J. Carson, IPEO Group Leader

Approved by: Dean R Pedersen Date 1/13/86
D. R. Pedersen, Program Manager

Reviewedby: C. A. Diokno Date 4/14/86
C.A. Diokno, Quality Engineer, QASO

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* The document number as it appears on this page only shall be used to identify this document. The last two digits denote the revision number of this document (see Revision Authorization block below).

This document is fully representative of the Document No. only when the revision number on its pages correspond with those in the index below.

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REVISION AUTHORIZATION

REVISION NUMBER	00	01	02	03	04	05	06	07	08
DCN NUMBER	–	008							
DATE	12/17/85	4/15/86							
APPROVED BY	[illegible]	[illegible]							

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1. INTRODUCTION

This Quality Assurance Program Plan (QAPP) implements and delineates the basic Quality Assurance requirements for the Argonne National Laboratory (ANL) Shutdown Heat Removal Test Assembly.

1.1 Scope

Implementation of the QAPP, is intended to assure that components, subassemblies, and assemblies are designed, procured, fabricated, assembled and tested in accordance to their specified criteria.

2. QUALITY ASSURANCE PROGRAM

This plan specifies the quality assurance requirements related to the Shutdown Heat Removal Test assembly. The degree of quality assurance applied to the project shall be appropriate to the nature and scope of work performed, the importance of the item or activity to safety, and satisfactory operating performance of the assembly.

The overall responsibility for implementing this quality assurance program rests with the program manager. Each responsible section manager or group leader has responsibility for the detailed implementation of quality assurance in his assigned area. The RAS-Quality Assurance Engineer (QAE) has responsibility for providing overall QA assistance, coordination and surveys.

3. CONTROL OF DESIGN

The design adequacy will be reviewed by persons other than those responsible for the original design. These reviewers will constitute a Design Review Board. The design review procedure will follow the general intent of the RAS, PPM, Section II-5.0.

Items that are related to safety during fabrication/assembly and operation of the test hardware will be evaluated by a separate safety committee.

4. CONTROL OF PURCHASED ITEMS AND SERVICES

Procurements of other than stock items, i.e., custom designed or critical items and materials (as determined by the project manager) will incorporate, where appropriate, drawings, specifications or special notes, certifications and Acceptance Criteria Listings (ACLs), e.g., Documentation is required for guard vessel and duct wall material and their surface condition).

Services and some procurements may be handled by service request. Any QA requirements will be specified on the Service Request or supplemental documents.

Procurement packages and service requests will be reviewed by responsible project personnel and the RAS-Quality Assurance Engineer to ensure necessary requirements have been included.

Procurement files shall be maintained and be retrievable for each purchased item. Documents shall include, as applicable, for each item (1) Purchase requisition, (2) Purchase order, (3) Service request, (4) any related correspondence and documents, (5) Receiving reports, (6) Inspection reports, and (7) Drawings and Specifications.

5. INSTRUCTIONS, PROCEDURES, DRAWINGS AND SPECIFICATIONS

Instructions, procedures, drawings, and specifications shall be prepared, as appropriate, for activities affecting quality. These documents shall include or reference criteria for determining that an item or assembly has met requirements.

Operation Process Work Sheets (OPWS) or similar type instructions and procedures shall be prepared for the installation and assembly of the test assembly. These documents will also indicate any inspections and testing required.

Any pre-experiment operations shall be planned and written procedures prepared and approved for start-up, check-outs, tests and inspections necessary to place the hardware into operation.

An operating manual or procedure shall be prepared and include procedures for start-up, normal, abnormal, emergency and shutdown operations and conditions. Separate procedures should be prepared for any tests not run in accordance with normal procedures or configurations.

An operating log shall be maintained and a review shall be made of the test results to determine if additional testing or data may be required.

The need for additional specific instructions or procedures, etc. shall be determined by the responsible project representative.

6. DOCUMENT CONTROL

All drawings, specifications, and other major documents, as determined by the project manager, shall be assigned a document number and entered into the ANL Document Control System. These documents shall be controlled and revised per the procedures given in the RAS-PPM, Section II-10.0.

The project manager, or his representative, shall provide distribution lists and instructions to the Document Control Center.

The following documents will be considered controlled documents for this project.

a. Drawings and Specifications
b. Design Requirements
c. QA Program Plan
d. Scoping Calculations
e. Other documents as designated by the project manager.

7. IDENTIFICATION AND CONTROL OF ITEMS

ϕ^1 Samples that represent the guard vessel and duct wall material shall be obtained and kept by the project manager.

If additional traceability requirements are needed, such action will be noted on drawings or specifications. This will be done where configuration or material history may be a performance factor.

8. CONTROL OF MEASURING AND TEST EQUIPMENT (M&TE)

The project shall develop an instrument and equipment list as part of the design requirements giving the measuring and test equipment required for the conduct of the testing program.

The list will include the intended use for the equipment and its required precision and/or accuracy requirements.

The M&TE requiring calibration shall be addressed on an individual basis. The method or type and frequency of calibrations shall be noted, e.g., calibrate with voltmeter traceable to NBS--annual recalibration.

M&TE requiring calibration shall be appropriately tagged and calibration procedures and records maintained.

ϕ^1DCN #R0408-008

The general calibration program and procedures for the RAS Division are given in the RAS-PPM II-13.0 and are to be used only as a guide for this program.

9. HANDLING, STORAGE, AND SHIPPING

Procedures shall be prepared and implemented for the handling, storage, and shipping of materials and fabricated items, as necessary, to prevent damage upon receipt, storage, installation, assembly, and testing.

10. CONTROL OF NONCONFORMING ITEMS AND CORRECTIVE ACTION

The reporting, control, and dispositioning of nonconforming material, during fabrication and installation, shall be in accordance to the RAS-PPM Chapter II-8.0, Section 8.4.5.

Nonconforming components may be used provided their presence will not have a deleterious effect on function or safety.

The causes of any significant conditions, as determined by the project manager, which are adverse to quality shall be identified and corrective action taken to prevent recurrences. The identified cause and corrective action for such significant conditions shall be documented and reported to appropriate management levels.

11. PROGRESS, TEST REPORTING AND DATA REQUIREMENTS

Rockwell International (RI) and General Electric (GE) shall be supplied with test reports, test results, computer codes, reviews and schedules on a mutually agreed upon schedule.

The primary measurements and inferred parameters needed to demonstrate performance are: total heat fluxes, convection heat fluxes, radiation heat fluxes, guard vessel temperatures, guard vessel heat transfer coefficients, duct wall temperatures and heat transfer coefficients, air flow rates and temperatures and pressures. These items will be backed up by detailed measurements of both temperature and velocity profiles.

12. QUALITY ASSURANCE AND PROJECT RECORDS

Records showing evidence of the performance of activities to stated requirements shall be maintained. The records shall be identified to test configuration, drawings, specifications and purchase orders, where applicable.

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Records should be maintained with final disposition as agreed to be ANL, RI and GE. The records to be maintained include but may not be limited to: Status Reports, Design Review Minutes, Design Requirements, QA Plans, Safety Review Minutes, Drawings and Specifications, Procurement and Receiving Inspection Records, In-House Fabrication, Test and Inspection Records, Nonconformance Reports, Log Books, Installation and Assembly Records, Inspection Disposition Reports, Operating Manuals and Procedures, Test Records and Reports.

ϕ^1 13. AUDITS

Audits to this Quality Assurance Plan will be performed by the ANL/E Quality Assurance and Safety Office (QASO).

ϕ^1 Reviewed by: C. A. Hicks [signature] QASO — 4/14/86 Date

ϕ^1DCN #R0408-008

APPENDIX D

RVACS/RACS Experiment Log Worksheets

RVACS/RACS Experiment Log Worksheet (Page 1)

Date: ____________ Time: ____________

Test ID: ______________________________

I. Test Conditions

A. Test Operation Mode: ___________________________

1. Constant guard vessel wall temperature at ____°F.

2. Variable guard vessel wall temperature at ____°F, ____°F, ____°F, ____°F, ____°F.

3. Constant guard vessel wall heat flux at ____°F.

4. Variable guard vessel wall temperature at ____°F, ____°F, ____°F, ____°F, ____°F.

B. Target system form loss coefficient (K) = ____.

Flat plate ID _______.

C. Target Reynolds No. Re = _________.

D. Natural or forced convection test? ____________________________

____

E. Gap width between guard vessel and duct walls (inches) _________.

F. Other requirements/conditions _________________________________

____

____

____

RVACS/RACS Experiment Log Worksheets (Page 2)

Experiment ID: __________

II. Pretest Operations	Date/Time Checked	By:
A. Slid-in (flat plate) damper check.		
1. The appropriate flat-plate damper for this test is: ID# ________	________	________
K = ________	________	________
2. Verify the appropriate flat-plate damper is fully inserted in position.	________	________
B. Verify fan operation (off, on, CFM speed) ________	________	________
C. Verify butterfly valve (closed, or extent open) ________	________	________
D. Verify roll-up door is fully open, and entrance-air path is unobstructed.	________	________
E. Verify that appropriate "Restricted Area" signs, ropes, and/or lights are at entrances, in place and operational.	________	________
F. Verify and record heater series and parallel string resistance measurements are in order, note any change from previous measurements, open etc., and action taken ____________________ ____________________	________	________
G. Verify thermocouple resistance measurements are in order, note significant changes, opens, etc., and action taken ____________________ ____________________	________	________
H. Verify safety interlocks operational		
1. 480 V power guard in place	________	________
2. Interlock alarms	________	________
3. GFI ________	________	________
4. All electrical grounds	________	________
I. Verify instrument calibration and/or zero adjustments.		
1. MKS Baratron Unit #1 (VOLU-rake Δp)	________	________
2. MKS Baratron Unit #2 (test section Δp)	________	________

RVACS/RACS Experiment Log Worksheets (Page 3)

Experiment ID: ______________

	Date/Time Checked	By:
II. Pretest Operations (cont'd)		
3. Traverse mechanism	______	______
4. Pitot-static tube/radiation shielded TC probe	______	______
5. Radiometer and heat flux meters	______	______
6. Wind monitor	______	______
7. VOLU-rake Δp/vel/mass flow rate	______	______
J. Verify control console readiness.	______	______
1. Power supplies and fans ready.	______	______
2. ISO-Paks/Unidriver and Unidriver/CAMAC interface ready.	______	______
3. Computer/DAS/CAMAC ready.	______	______
4. Alarm indicators (GFI, local, remote, and 480 VAC) ready.	______	______
5. Heater status (GFI alarm, 480 VAC, 20 channels) ready.	______	______
6. DORIC data loggers: Unit #1 ready	______	______
Unit #2 ready	______	______
Unit #3 ready	______	______
7. Instrumentation electronics.	______	______
a. MKS Baratron Unit #1 ready.	______	______
b. MKS Baratron Unit #2 ready.	______	______
c. Pressure transducer electronics ready.	______	______
d. Barometer electronics ready.	______	______
e. Wind speed and azimuth electronics ready.	______	______
f. Room humidity/temperature electronics ready.	______	______
g. Traverse mechanism electronics ready.	______	______
K. Verify prepositioning of measurement instrumentation in test assembly.	______	______
1. Inlet room temperature measurement instrument in proper position and ready.	______	______
2. Inlet barometric pressure measurement instrument ready.	______	______
Elevation: ______________	______	______
3. Inlet radiation shielded TCs.	______	______
4. Outlet VOLU-probe ready.	______	______
5. Outlet radiation shielded TCs.	______	______

RVACS/RACS Experiment Log Worksheets (Page 4)

Experiment ID: ____________

II. Pretest Operations (cont'd)	Date/Time Checked	By:
6. Traverse mechanism w/pitot-static tube and shielded TC probe in 1st specified location and ready.	________	________
Tot. No. of locations required _____	________	________
Tot. No. of measurement positions in a single traverse _______.	________	________
7. Radiometers (2) and heat flux meters (2) in specified starting locations and ready.	________	________
Tot. No. of locations required _____	________	________
8. Duct wall emissivity measurement instrument probe in specified starting location and ready.	________	________
Tot. No. of locations required _____	________	________
9. Guard vessel emissivity measurement. Instrument probe in specified starting location and ready.	________	________
Tot. No. of locations required _____	________	________

III. Operations During Test at Thermal Equilibrium

Note: At least two persons are required to be in the test area for any work related activity around the test assembly.

	Date/Time Checked	By:
A. Time required to attain thermal equilibrium ____________.	________	________
B. Actual measured conditions at thermal equilibrium. ________	________	
1. Guard vessel wall temp. ____°F.	________	________
2. Guard vessel wall heat flux ___kW/ft^2	________	________

RVACS/RACS Experiment Log Worksheets (Page 5)

Experiment ID: ___________

Date/Time Checked ______ By: ______

III. Operations During Test at Thermal Equilibrium (cont'd)

C. Record weather conditions (at start and each hour after equilibrium or when abrupt changes are observed).

Time (start + each hr after TE)	Temperature: Room at Inlet	Temperature: Outdoor at Tower	Barometric Pressure: mm Hg	Barometric Pressure: psia	Humidity RH%	Wind: Speed mph	Wind: Azimuth	Weather: sunny, cloudy, rain, snow

RVACS/RACS Experiment Log Worksheets (Page 6)

Experiment ID: ____________
Date: ____________

III. Operations During Test at Thermal Equilibrium (cont'd)

D. Requirements and verifications for traverse mechanism access port locations and measurement positions.

1. Access port locations required are indicated below by reference to corresponding DAS PNUM and PID (see Table 3-12, and 3-15 in Test Plan).

2. Measurement positions in a single traverse (referenced from the duct wall) are as follows: ______________________________
____

Access	Port Locations		Verified Locations			Access	Port Locations		Verified Locations		
No.	PNUM	PID	Zone #	EL.	By:	No.	PNUM	PID	Zone #	EL.	By:
1						16					
2						17					
3						18					
4						19					
5						20					
6						21					
7						22					
8						23					
9						24					
10						25					
11						26					
12						27					
13						28					
14						29					
15						30					

RVACS/RACS Experiment Log Worksheets (Page 7)

Experiment ID: ____________
Date: ____________

III. Operations During test at Thermal Equilibrium (cont'd)

E. Requirements and verifications for radiometer and heat flux access port locations.

1. Radiometer and heat flux access port measurement locations required are indicated below with reference to corresponding DAS PNUM and PID numbers (see Table 3-15 of Test Plan).

Radiometer Access Port Locations			Verified Locations			Heat Flux Meter Access Port Locations			Verified Locations		
#	PNUM	PID	Zone #	El.	By:	#	PNUM	PID	Zone #	El.	By:
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					

RVACS/RACS Experiment Log Worksheets (Page 8)

Experiment ID: ____________
Date: ____________

III. Operations During test at Thermal Equilibrium (cont'd)

F. Requirements and verifications for duct wall emissivity measurements - (side wall access port locations and horizontal measurement positions).

1. Access port locations required are indicated below by reference to corresponding DAS PNUM and PID numbers (see Table 3-15 in Test Plan).

2. Horizontal measurement positions are referenced from the side wall as follows: ________________________

Emiss. Radiometer Access Port Locations			Verified Locations			Emiss. Radiometer Access Port Locations			Verified Locations		
#	PNUM	PID	Zone #	El.	By:	#	PNUM	PID	Zone #	El.	By:
1						4					
2						5					
3						6					

RVACS/RACS Experiment Log Worksheets (Page 9)

Experiment ID: ____________
Date: ____________

III. Operations During test at Thermal Equilibrium (cont'd)

G. Requirements and verifications for guard vessel wall emissivity measurements - (duct wall access port locations).

1. Access port locations below correspond to DAS PNUM and PID numbers (see Table 3-15 in the Test Plan).

2. The sensor distance from the guard vessel wall is fixed at 1-inch.

3. Special instructions: ____________________________________

____

Emiss. Radiometer Access Port Locations			Verified Locations			Emiss. Radiometer Access Port Locations			Verified Locations		
#	PNUM	PID	Zone #	El.	By:	#	PNUM	PID	Zone #	El.	By:
1						7					
2						8					
3						9					
4						10					
5						11					
6						12					

RVACS/RACS Experiment Log Worksheets (Page 10)

Experiment ID: ____________

Date: ____________

III. Operations During test at Thermal Equilibrium (cont'd)

H. Operation of building exhaust fan.
Date/time of operation: ______________________

1. Reason for fan operation: ______________________________

____

2. Requested/authorized by: ______________________________

Typical Hottest Temperatures and Velocity Before Fan-On			Typical Hottest Temperatures and Velocity After Fan-On		
G.V. Wall °F	Outlet Air °F	Air Velocity	G.V. Wall °F	Outlet Air °F	Air Velocity

I. Other tasks to be performed:

1. ____

____

2. ____

____

3. ____

____

4. ____

____

5. ____

____

RVACS/RACS Experiment Log Worksheets (Page 11)

Experiment ID: ____________
Date: ____________

III. Operations During test at Thermal Equilibrium (cont'd)

J. Authorization to power-down.

1. All experiment log worksheet test requirements and verifications have been completed, reviewed, and approved by ________________, and power-down is authorized by ________________________.

IV. Posttest Operations

A. Once approval to "power-down" is given by the responsible engineer, and the system is at "zero-power", posttest operations are begun.

B. If the test section temperature is over 200°F the forced-flow fan will be operated at full speed with the butterfly valve fully open, and a highly restrictive flat-plate damper will be inserted into position. The roll-up door will need to remain open, and the test area will be manned until the temperature of the test section is reduced to below 100°F.

1. Test section hottest temperature at power down: ____°F

2. Fan operation ____

3. Butterfly valve position ______________________________

4. Flat-plate ID used ____________________________________

5. Roll-up door open _____________________________________

6. Fan operated for (time duration) _____ when test section temperature was ____°F.

7. Fan off, butterfly valve closed, roll-up door closed and final shutdown procedures commenced at (time) __________, authorized by: ____________.

C. Control console shut-down procedures commence.

D. Final Shutdown Procedures

1. When the test section has cooled to about 100°F the fan should be turned off, and the butterfly valve damper closed.

RVACS/RACS Experiment Log Worksheets (Page 12)

Experiment ID: ____________
Date: ____________

IV. Posttest Operations (cont'd)

2. After the test assembly has cooled to about 90°F the solid plate damper should be inserted.
Note: This operation is anticipated to be required primarily during the cold seasons (autumn, winter, and spring) to restrict the natural convective flow of warm room air out through the chimney.

3. The roll-up door may be closed gradually as the test assembly cools and the air draft demand decreases (especially during cold, and inclement weather).

4. Completion of the "on-line" data reduction, and hard copy data graphing will be performed and verified as required; also, the test data recorded on the DAS winchester disk will be copied to 8-in. floppy disks (type RX02 or RX01).

5. Completion of the final shutdown procedures for the control console will be performed.

6. It shall be verified that all the test data required to be saved has been copied to floppy disks, the disks are properly labeled, and stored in appropriate carrying containers.

7. All the test data floppy disks are to be given to the lead experimenters or transferred directly to B. Baldwin for up-loading to the PDP 11/73 in Building 208.

E. All on-line data reduction completed, reviewed, and approved by: ____________________

F. Verify that all the required test data on the DAS Winchester disk was copied to floppy fisks, and that disks were labeled, and stored in appropriate carrying containers. Verified by: ________________

G. Control console shutdown procedures were completed at (date/time) __________________, and reviewed and approved by ______________.